Staff Report of the

CALIFORNIA REGIONAL WATER QUALITY CONTROL BOARD

CENTRAL VALLEY REGION

A TOTAL MAXIMUM MONTHLY LOAD MODEL FOR THE SAN JOAQUIN RIVER

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF TABLES (continued)

LIST OF TABLES (continued)

LIST OF FIGURES

LIST OF FIGURES - (continued)

FIGURE Page

LIST OF ABBREVIATIONS

CCID - Central California Irrigation District

CVP - Central Valley Project

CVRWQCB - Central Valley Regional Water Quality Control Board

DOP - drainage operation plan

DSA - Drainage Study Area

EC - electrical conductivity

LA - load allocation

M.S. - Mud Slough (N)

MOS - margin of safety.

S.S. - Salt Slough

Se - selenium

SJR - San Joaquin River

SJRIO2 - San Joaquin River Input/Output model, version 2

TDS - total dissolved solids

TMDL- Total Maximum Daily Load

TMML - Total Maximum Monthly Load

TMMLSJR - Total Maximum Monthly Load model for the San Joaquin River

U.S. EPA - United States Environmental Protection Agency

WLA - Waste Load Allocation

WY - Water year; in California the water year runs from October to September.

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EXECUTIVE SUMMARY

Section 303(d) of the Federal Clean Water Act requires states to submit lists of water quality impaired water bodies and to develop a Total Maximum Daily Load (TMDL) for those water bodies. The California State Water Resources Control Board has listed the San Joaquin River (Fig. 1a & b) between the Mendota Pool and Vernalis as a water body that is water quality impaired due to elevated levels of selenium originating from agricultural subsurface drains.

In response to this listing, several hydrologic models were reviewed to determine their appropriateness for developing selenium load allocations for the San Joaquin River downstream of the Merced River. It was found that the models reviewed were either inappropriate for the San Joaquin (US EPA single design flow, steady state models) or relied heavily upon calculations based on a limited data set (SJRIO-2 and Swain-Quinn).

Based on the limitations of the reviewed models, a decision was made to develop a simple spreadsheet model to calculate the Total Maximum Monthly Load for the San Joaquin River (TMMLSJR). This model relied largely on historic (Water Year 1970-91) flow data collected at the Patterson gauge on the San Joaquin River. The historic record was initially divided into three water year-type flow regimes and four seasonal flow regimes. The monthly time step was chosen since most agricultural districts lack the facilities required to manage drainage on a daily basis.

The TMMLSJR model and a single design flow model were compared using the same exceedance rate (once every three years) and water quality objective (5 μg/L). Model results indicated that the allowable load for Dry/Below Normal years is increased by 100% and the load for Above Normal/Wet years is increased by 107% when using the TMMLSJR model rather than the single design flow model. The allowable load for critical years is decreased by 7%.

The TMMLSJR model was used to evaluate two different averaging periods for the water quality objective and several different violation rates. Changing the water quality objective from a four-day average water quality objective to a monthly mean increased the allowable load by 24%-32%. Increasing the violation rate from once every three years to once every five months increased the allowable load by 60%-120%. It was also found that relaxing the objective for critical years was equivalent to changing the violation rate from once every three years to once every nineteen months.

A suggested model improvement that should enhance the ease of regulatory implementation would be to redefine the water year from October-September to January-December. This change is suggested since there is a higher probability of correctly predicting water year-type later in the rainy season rather than at the beginning. In addition, statistical comparisons of the two definitions show that the January-December definition is the more appropriate.

In summary, the waste load allocation (the load allocated to the regulated discharger) was found to be highly dependent on the acceptable rate of violation of the water quality objective and less dependent on the averaging period of the objective. Significant reductions in discharge, along with temporal redistribution of discharge, may be necessary to meet a 5 μg/L objective on a consistent basis.

INTRODUCTION

Section 303(d) of the Federal Clean Water Act requires states to submit lists of water quality impaired water bodies and to develop a Total Maximum Daily Load (TMDL) for those water bodies. The California State Water Resources Control Board has listed the San Joaquin River (Fig. 1a & b) between the Mendota Pool and Vernalis as a water body that is water quality impaired due to elevated levels of selenium. The selenium in the San Joaquin River was found to originate largely from the subsurface drainage of six agricultural districts encompassing 90,000 acres of irrigated land.

The California Regional Water Quality Control Board, Central Valley Region, emphasizes reductions in agricultural drainage volume and pollutant loads through best management practices as the most appropriate method for meeting water quality objectives[1] in the San Joaquin River (California State Water Resources Control Board, 1989). Submittal of Drainage Operations Plans (DOPs) from local districts contributing to the generation of subsurface drainage has been required since 1989.

The combination of the prolonged drought in California, along with the focus on drainage management through DOPs, has led to significant reductions in pollutant loads (Fig. 2). Though water quality in the San Joaquin River has improved (Fig. 3), the water quality objectives are still exceeded, and water quality impacts in nondrought years are unclear.

One way to evaluate the long-term impact of selenium pollutant loads is to determine the ability of the San Joaquin to assimilate that load. Since the assimilative capacity of the San Joaquin River will vary from year to year, a given amount of pollutant discharge in a "wet" year may not lead to a violation of the water quality objective, whereas the same level of pollutant discharge in a "dry" year may lead to a significant number of violations.

Often, these variations in assimilative capacity are not recognized when concentration based regulatory limits are developed. The regulated entity may not be required to take actions to reduce pollutant discharge in a given year if water quality objectives are being met; even though that same level of discharge may lead to violations in a year in which the receiving water has less assimilative capacity.

Rather than basing regulatory action on the vagaries of the assimilative capacity of a water body in a given year, the US EPA has developed a general method for relating the concentration objective to the assimilative capacity of the receiving water. The method results in the calculation of a total maximum daily load (TMDL). An appropriately designed TMDL model would allow the Regional Board and affected agricultural entities to determine the degree of pollutant load reduction necessary to meet water quality objectives over the long-term.

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[1] The water quality objective (also referred to as "objective") is the term used by the State of California to describe the numerical water quality parameter which will protect the most sensitive beneficial use in a water body. This term will be used throughout the report, rather than the US EPA term "water quality standard", which refers to a specific criteria which has been adopted to protect a particular designated beneficial use.

This report will review the US EPA method of relating concentration based objectives to pollutant discharge. Two general US EPA models will be reviewed along with two pollutant transport models designed specifically for the San Joaquin River. Appropriate components of these four models are then used to develop a screening level methodology for determining the assimilative capacity of a western stream with non-point source pollution problems.

BACKGROUND[2]

Of the 5 million acres of land irrigated in the San Joaquin Valley (California Department of Water Resources, 1993), 1.6 million acres receives water from either the Delta-Mendota Canal of the Central Valley Project (CVP) or the San Luis Unit of the CVP and the State Water Project (i.e., the California Aqueduct). In order to maintain crop productivity in the San Joaquin Valley, the U.S. Bureau of Reclamation committed to building a drainage outlet for 300,000 acres of land with shallow ground water problems. By 1975, 85 miles of the San Luis Drain, which was to extend to the Sacramento-San Joaquin Delta, had been completed, along with collector drains and the first phase of a regulating reservoir (Kesterson). The construction was halted due to lack of funding and the unknown impacts of drainage on the Delta environment.

Drainage water was discharged and evaporated in Kesterson beginning in 1975. This drainage came principally from 42,000 acres of land in the Westlands Water District. The 1983 discovery of deaths and deformities of aquatic birds attributed to elevated levels of selenium led to the closing of Kesterson in 1986 and the cessation of offsite discharge from the 42,000 tile drained acres within Westlands Water District.

Historically, agricultural districts to the south of Kesterson and north of Westlands had discharged subsurface and surface drainage through canals owned and maintained by Grasslands Water District, the local water supplier for 50,000 acres of private and public wetlands. Due to a small firm supply of federal water (55,000 acre-ft), Grasslands Water District supplemented its water supply with the agricultural discharge. Any water not used in the Grasslands flowed to two sloughs (Mud Slough (north) and Salt Slough) tributary to the San Joaquin River. A schematic of major features of the study area is shown in Figure 1b.

The agricultural discharge from several districts (Table 1) of the Drainage Study Area (DSA) in the Grasslands Watershed was also found to contain elevated selenium levels. This finding led duck club owners and refuge managers to gradually reduce their use of agricultural discharges that were high in selenium. By 1985, few wetland diversions of agricultural discharge were being made. Elimination of wetland diversions resulted in an initial increase of approximately 60,000 acre-ft annually (San Joaquin Valley Drainage Program, 1990) in the amount of high selenium drainage water released directly to the San Joaquin River.

In September 1989, the State Water Resources Control Board (by Resolution No. 89-88) adopted the water quality objectives for selenium (Table 2) contained in the Central Valley Regional Water Quality Control Board (CVRWQCB) Basin Plan. The intent behind objectives adopted by the Regional Board was to protect the wetlands and the San Joaquin River downstream of the Merced River. The Regional Board felt that during critical years, dilution from the Merced

[2] The background section is largely from the San Joaquin Valley Drainage Program (1990).

River would not be sufficient to meet a 5 µg/L objective. A relaxation in the objective for critically dry years was, therefore, allowed.

The Regional Board recognized at the time that Mud Slough (north), Salt Slough, and the San Joaquin River upstream of the Merced River did not carry enough dilution water to meet a 5 µg/L objective. The objectives in these stream reaches were set to protect downstream beneficial uses. It was assumed that if the 10 µg/L objective could be met, the Merced River flow would be of a sufficient quantity to reduce the San Joaquin River concentration to 5 µg/L.

The Regional Board felt that all concentration objectives could be met by improving irrigation practices. Improvement in irrigation efficiency would decrease the amount of water discharged from the tile drainage systems and, thereby, decrease the selenium load discharged to the San Joaquin River.

Although the Regional Board implementation strategy for complying with selenium objectives implicitly acknowledges that selenium loads must be reduced, no explicit load target was developed. The success in reducing loads and improving water quality during the drought (1987-1992) raises two important questions: 1) How much additional reduction is required in drought years to meet objectives on a consistent basis, and 2) When water supplies increase (the drought ends) and drainage discharge increases, will pollutant loads lead to violations of water quality objectives?

These questions can be answered by using a model that evaluates the assimilative capacity of the San Joaquin River over the long term.

WHAT IS A TMDL?

The authors of the Federal Clean Water Act recognized that the concentration of a pollutant in a receiving water is a result of the sum of the mass of the inputs from the individual sources of the pollutant divided by the volume of the receiving water.

$$(1) \qquad C_R = \frac{\sum_{i=1}^{n} C_i \, Q_i}{Q_R} \quad ; \quad Q_R = \sum_{i=1}^{n} Q_i$$

Where C_i is concentration and Q_i is flow rate for "n" individual pollutant sources. C_R and Q_R are the concentration and volume of the receiving water, respectively. When C_R is greater than the water quality objective (WQO), an analysis of the individual contributions to the total pollutant load is necessary. By reducing the most significant contributions to the total pollutant load, C_R can be reduced below the water quality objective.

To determine the total maximum allowable load, C_R is set equal to WQO. If a daily load limit is required, equation (1) becomes:

(2) Total Maximum Daily Load (TMDL) = (WQO) (Q_R)

The reduction in pollutant load will require adjustments in flow and/or concentration from those sources amenable to pollution control strategies.

$$(3) \qquad \text{Therefore, TMDL} = \sum_{i=1}^{j} C_{i,\ Adj}\, Q_{i,\ Adj} + \sum_{i=1}^{k} C_i \, Q_i$$

$$(4) \qquad \text{and} \quad Q_R = \sum_{i=1}^{j} Q_{i,\ Adj} + \sum_{i=1}^{k} Q_i$$

for "j" pollutant sources that can be controlled and "k" sources that can not be controlled (j + k = n). The "adj" subscript denotes pollutant sources whose flow and/or concentration can be adjusted.

In its guidance on TMDL development (US EPA, 1986), the US EPA recognized that all sources of pollutant loads could not be explicitly defined, so three general components of the TMDL were defined:

WLA - waste load allocation for point sources.

LA - Load allocation for non-point sources and background.

MOS - A margin of safety which accounts for uncertainties in the determination of the WLA or LA.

(5) TMDL = WLA + LA + MOS

The Federal Clean Water Act only provides the US EPA with authority to regulate point sources, so it was envisioned that by reducing the well defined point source load contributions (WLA), the TMDL and water quality objective could be met.

Since the 1986 guidance, the US EPA revised TMDL guidance (US EPA, 1991) has recognized that non-point sources are often a significant component of a pollutant problem. Since non-point sources are by nature less well defined, the complexity of pollutant load models will vary depending on the amount of data available and extent of the problem.

Two simple steady-state US EPA models and two transport models specific to the San Joaquin River are reviewed below.

MODELS THAT CAN BE USED TO DEVELOP A TMDL

The US EPA Hydrologically Based and Biologically Based Steady State Models

The hydrologically-based method (XQY) uses a log-Pearson Type III flow estimating technique or a distribution-free technique to determine design flow. Design flows are calculated as annual X-day average low flows with a return period of Y years. The design flow for "Criterion Continuous Concentration" (the chronic toxicity criteria), expressed as a 4-day average concentration, is normally computed by determining the annual low seven-day average flows with a return period of 10 years (i.e., the annual seven-day average low flow would occur once every ten years).

The distribution-free technique is the most straightforward. The low seven-day average flows for each year of record are calculated and rank-ordered from lowest to highest. The flow at the (n+1)/y rank is chosen as the design flow, where "n" is the total number of years.

For the log Pearson Type III method, the design flow is calculated as follows:

$$\text{Design Flow} = \exp(u + K\{q,y\}\ s)$$

u = mean of natural log of annual low flows

s = standard deviation of the natural logs of the historic low flows

q = skewness coefficient of natural logs of historic low flows

K = frequency factor for skewness q and return period y.

The biologically-based design flow uses a much more complicated algorithm to determine the design flow. For criterion based on the 4-day average concentration, the 4-day running harmonic means are calculated for the whole period of record. The algorithm then determines a design flow, such that the 4-day average concentration objective would be exceeded once every three years on average.

Inherent within this procedure is the assumption that ecosystems need 15 years, on average, to recover from the severe stresses brought on by a drought. A drought is defined as a low flow period in which five or more excursions occur within a 120-day period. If five excursions occur within the drought period, no other excursions can occur within a 15-year period of record; otherwise, the excursion rate would be greater than once every three years.[3]

The XQY and Biologically-Based design flow methods have the following characteristics:

1) one design flow is calculated, which is used to compute a maximum daily load;

2) the design flow is developed from low flow events; and

3) an acceptable rate of violation is explicitly expressed within each methodology.

Characteristics (1) and (2) evolve from the underlying steady state modelling assumption "that the composition and flow of the effluent of concern is constant", which implies that "the ambient (instream) concentration of a pollutant can be considered to be inversely proportional to stream flow" (US EPA, 1986). If the effluent concentration and flow is relatively constant, the worst case scenario occurs during the lowest periods of flow in the stream. Given these assumptions, developing a single design flow is appropriate.

Although applicable to many point source pollution problems, the assumption of relatively constant pollutant discharge is not valid for agricultural drainage discharges in the study area. A plot of average monthly loads of selenium from available historical data reveals significant seasonal variation in discharges. Superimposed on the variability in pollutant discharge is significant variability in instream flow (Fig. 4).

Although a single design flow may not be appropriate, the introduction of the violation rate is illuminating. The "phased approach" to load reductions for non-point sources advocated by the US EPA can be defined in terms of a "phased" reduction in violation rate. Initial load allocations can be based on a high frequency of violation (eg. once every five months) and the final load target can be based on a low frequency of violation (eg. once every three years). This concept will be applied later when the TMMLSJR model is described.

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[3] The exceedance (excursion) rate is the violation rate of the water quality objective.

The San Joaquin River Input-Output Model

The San Joaquin River Input-Output Model (SJRIO-2) is a mass balance model which determines the monthly water quality and flow in the San Joaquin River based on the inflow and outflow from each reach of the River (Kratzer, *et al.*, 1987; Rashmawi, *et al.*, 1989; Grober, *et al.*, 1992). The factors considered which affect flow and quality include: discharges, diversions, tributary inflow, groundwater inflow/outflow, evaporation/precipitation, riparian transpiration. In many cases, quantification of the above factors is approximated due to the limited availability of data. SJRIO-2 does allow for correction of errors in calculated flow and salinity by comparison of calculated values with measured values at three stations on the San Joaquin River. Any error between observed and predicted values is corrected by distributing the error among the various inputs and outputs upstream of the calibration station.

The impact of reductions in drainage outflow can be modelled by adjusting the input data for Mud and Salt Sloughs - the two tributaries to the San Joaquin River which carry the overwhelming majority of the selenium load in the river basin. An appropriate TMDL (or TMML, since the time step is monthly) could be developed by modifying the historical loads carried by the sloughs until the calculated downstream (San Joaquin River) water quality was acceptable. The diagram in Figure 5 depicts the process that would be used to determine an appropriate load.

The difficulty in using SJRIO-2 to evaluate drainage load reduction what - if scenarios is that the available historical data for Mud Slough (north) and other inputs is limited. SJRIO-2 considers water years 1977-91, but historical flow data is not available for Mud Slough (north) for calendar years 1978, 1980-84. In addition, ground water contributions to the San Joaquin River are based on calculations as are agricultural return flows along the San Joaquin River.

When the model is calibrated, any errors inherent in these assumptions are largely corrected. But when drainage reduction scenarios are developed, no corrections are made and the effect of the errors on scenario results are unknown.

Differences between uncalibrated model results and observed values are up to 20 percent in normal water year types and can be much greater in drought years (Les Grober, personal communication, 1993). The larger errors in drought years occur due to the greater relative contribution of agricultural return flows and ground water to total river flow. These two components represent the greatest uncertainty in the model since their values are derived from calculations.

In addition to modelling historical data, SJRIO-2 can be used to generate and model stochastic data. Flow and total dissolved solids (TDS) values are generated for the three east side tributaries and the San Joaquin River at Lander Avenue by performing a time series analysis on thirteen years of historical data. The time series preserves the spatial and temporal correlation of the generated data for these sites.

Stochasticity is introduced to other model components based on water year type. Mean monthly flow and TDS values for each water year type are further adjusted based on subjective uncertainty coefficients. Inputs for Mud and Salt Sloughs are held constant for all water years established for each component.

The use of time series analysis in effect extends the flow record, although the extension is based upon a limited (13-year) historical record. The extension assumes that the mean and standard deviation of the time series will be preserved. The introduction of stochasticity does address some of the concerns in the uncertainty of east side tributary flows and TDS. This extension in the flow record and reduction in uncertainty gives a more realistic glimpse into what the long term flows and salt concentrations might look like in the San Joaquin River. The main difficulties in applying this model directly to determining selenium load allocation are:

1) a stochastic component is not introduced for the input that carries the greatest selenium load - Mud and Salt Slough; and

2) uncertainties associated with other model components still predominate during the period of greatest concern - low flow.

Although the base model and stochastic model components of SJRIO-2 offer significant advantages with their thorough accounting of river inputs and outputs, the uncertainty of data inputs which predominate at low flows (especially Mud and Salt Slough) lessens the desirability of using the model for determining load allocations.

<u>Swain/Quinn Spreadsheet Model</u>

Swain and Quinn (Swain and Quinn, 1991; Swain 1991) developed a spreadsheet model to assess the assimilative capacity of the San Joaquin River (SJR). The model was used to support the Bureau of Reclamation plan formulation for drainage management in the San Luis Unit of the Central Valley Project. The model was used to assess the degree to which the San Joaquin River could assimilate drainage discharged by the Federal contractors in the Grassland Watershed of the San Luis Unit (i.e. the DSA minus Firebaugh and CCID). A 30-year period (1961-1990) was evaluated.

The Swain/Quinn model recognized that prior to 1986, much of the drainage from the DSA was applied to wetlands. The volume of drainage from the DSA reaching the SJR was much less than under current conditions of no wetland use of drainage. Since much of the drainage was intercepted by wetland operators, the timing of the discharge of this drainage coincided more closely with wetland discharge patterns rather than agricultural discharge patterns.

Swain and Quinn attempted to adjust historical flows and selenium loads in light of the current management of agricultural drainage discharge. The procedure used was as follows:

1) Determine historical flows and selenium loads for the wetlands, DSA, Mud Slough (north), Salt Slough, and the San Joaquin River near Newman.

2) Subtract DSA and wetland flows from Mud and Salt Sloughs to produce an estimate of background flow in the sloughs.

3) Estimate background flows and loads in the SJR by subtracting Mud and Salt Slough flows and loads from the San Joaquin River near Newman.

4) Estimate slough flows and loads (less the DSA drainage) by adding the background and wetland components - the "reconstructed" sloughs.

5) Add the "reconstructed" flows and loads from the sloughs to the background component of the San Joaquin River.

Steps 1-5 produce a portrait of the SJR without drainage from the DSA. The total allowable load for the SJR near Newman was found by multiplying the water quality objective times the reconstructed flow for the Newman site. The allowable drainage discharge was found by subtracting the reconstructed load at the Newman site from the total allowable load.

Although the Swain/Quinn model provides a valid method for determining allowable drainage discharge, it suffered from a lack of data required for step one. Historic wetland flow data does not exist, so estimates were made. Historic flow and load data for the DSA and sloughs is severely limited prior to 1986, so various estimation techniques were used to develop the 1960-1985 data set.

The combination of the construction of historical flow and load values from limited data, along with corrections to these constructions, lead in many cases to negative background selenium load values for the San Joaquin River at Newman. When the negative background load is subtracted from the total allowable load, the result is an allowable drainage load that is higher than the assimilative capacity of the San Joaquin River. Allowing more discharge from the DSA than the River could assimilate would be allowable only if losses of selenium occurred between the DSA measuring points and the River.

Although annual load data (Fig. 2) appears to indicate that such "losses" occur in most years between the DSA and the sloughs, the change in selenium load between these two points is not consistent when observed on a monthly basis (Fig. 6). A similar loss apparently does not occur between the sloughs and River (Fig. 7).

The difference in load leaving the DSA and reaching the sloughs can be due to one or a combination of factors: poor flow data from the DSA, selenium uptake by vegetation, mixing of drainage and wetland supplies, or diversion by farmers. Since the changes in load between the DSA and sloughs is not consistent, it is inappropriate to assume that losses are occurring at all times.

In summary, the load values developed using the Swain/Quinn methodology may not be appropriate for developing load allocations since:

1) The model relies on a limited flow and water quality data set (mostly from 1986-90) to reconstruct the historical record (1961-90); and

2) an assumption of selenium losses is accepted without sufficient validation. If this assumption is not valid, the load allocated to the districts would exceed the assimilative capacity of the San Joaquin River.

A SIMPLE TOTAL MAXIMUM MONTHLY LOAD MODEL FOR THE SAN JOAQUIN RIVER (TMMLSJR)

Although SJRIO-2 and the Swain/Quinn model provide effective methods for calculating selenium loads in the San Joaquin River, their reliance on limited data sets adds to the uncertainty of model results. It is, therefore, desirable to develop a model which maintains much of the methodological strength of the aforementioned models without the large data requirements. In addition, it will be desirable to relate allowable loads to a violation rate (as described previously in the US EPA models). The development of such a relationship will allow the regulators and regulated community to clearly understand the benefits (in terms of decreased violation rates) of load reductions.

The following discussion is a much expanded version of a paper entitled, *Development of a Selenium TMDL for the San Joaquin River* (Karkoski, *et al.*, 1993) and will include modifications to the procedure outlined in that paper.

The goals of the TMMLSJR model are the following:

1) provide load values that can be used for policy analysis and as regulatory limits;
2) rely on the fewest number of assumptions as possible; and
3) recognize year to year and within year variations in hydrological conditions.

In addition to the above goals, the TMMLSJR model must consider an appropriate time step. A monthly time step is examined rather than a daily time step since many of the districts would have difficulty in making daily adjustments in the amount of discharge leaving the district outlet. A daily discharge limit could be developed if the facilities (holding ponds and/or district wide recirculation systems) necessary for daily management of drainage were constructed.

The TMMLSJR model contains three main components:

1) a semi-quantitative division of the historical flow record into flow regimes based on water year type and season;

2) a determination of design flow for each flow regime based on a desired excursion rate; and

3) calculation of the total allowable load for each flow regime and division of the allowable load among regulated discharges, unregulated discharges, and a margin of safety.

The first two components focus on manipulation of the flow record at the compliance point. Since the flow record at the compliance point is not complete, a description of the determination of the missing flow data is given below. In addition, it is desirable to compare the 4-day average concentration objective with the monthly mean objective. A method for developing this comparison is also described.

Developing the Flow Record

Construction of Flow Record for the Compliance Point

The compliance point for the objectives set on the San Joaquin River downstream of the Merced River is at Crows Landing Bridge. Flow data for Crows Landing is available for WYs 1941-72.

Flow data is also available for one site six miles upstream of Crows Landing at the San Joaquin River near Newman (WYs 1912 - present) and for one site six miles downstream of Crows Landing at the San Joaquin River at the Patterson Bridge (WYs 1938 - present).

Dam construction has effectively changed the hydrology at the compliance point. The Friant Dam was completed in the upper San Joaquin River in 1942 and effectively diverts all water in the upper watershed with the exception of flood flows. The major sources of water in the San Joaquin River at Crows Landing come from Salt Slough, Mud Slough (north) and the Merced River.

The completion of construction of the New Exchequer Dam on the Merced River in 1966 increased the capacity of that reservoir from 281,000 acre-ft to 1,024,000 acre-ft. Since this change in reservoir capacity has had a significant impact on the hydrology of the Merced River downstream of the dam, only the flow record (U.S. Geological Survey, 1970-91, California Department of Water Resources, 1970-91) for the period following completion and filling of the New Exchequer Dam is considered (water years 1970-91).

Only three years of flow data for the Crows Landing site is available (1970-72) for the period under consideration. Therefore, the remainder of the flow record must be derived from either the Newman or the Patterson site. The accuracy of measurement for all three sites is good (California Department of Water Resources, 1981); meaning, the error is less than 10 percent.

A comparison between the three sites was made for three years of overlapping flow records (Table 3). This comparison indicates that the relative and absolute difference between Crows Landing and Patterson flow readings is less than the difference between Crows Landing and Newman flow readings.

In order to determine the relative difference between Crows Landing and Patterson for WYs 1973-91, SJRIO-2 was used. SJRIO-2 was run in the "calibration" mode. In this mode, corrections are made in the model until actual and calculated monthly flow values agree to within 10% at sites for which data is available. Flow values between these calibration points can then be found.

For WYs 1977-91, the ratio of the model calculated flow at Crows Landing to model calculated flow at Patterson was found. It was assumed that:

$$\text{(6)} \qquad \frac{Q_{\text{Crows, Actual}}}{Q_{\text{Pat, Actual}}} = \frac{Q_{\text{Crows, Model}}}{Q_{\text{Pat, Model}}}$$

$$\text{(7)} \qquad Q_{\text{Crows, Actual}} = \frac{Q_{\text{Crows, Model}}\,(Q_{\text{Pat, Actual}})}{Q_{\text{Pat, Model}}}$$

where "Q" is flow rate in acre-feet/month.

As can be seen in Table 4, the ratio of model flow results for Crows Landing and Patterson is above 0.9 for 75% of the months and above 0.8 for 98% of the months. The average ratio is 0.94. For the time period the model does not cover (1973-76), the ratios found for hydrologically similar water years are used.

Developing a Monthly Equivalent of the Four-Day Average Objective

The Regional Board Basin Plan objectives are based on a monthly mean. The US EPA objective for the San Joaquin River is 5 µg/L based on a four-day averaging period. To make comparisons between the two objectives, it was necessary to develop a monthly equivalent of the four-day average objective.

This was accomplished by calculating the low four-day average flow at Patterson for every month of the period of record. The equation for calculating the four-day average flow on "n"th day of the month is:

$$(8) \qquad \text{4-Day Avg. Flow} = \frac{\sum_{i=0}^{3} Q_{n-i}}{4}$$

The four-day average flow values for the first three days of a month would include data from the previous month. When comparing the monthly mean flow to the four-day average flow for the month, including data for the previous month would be undesirable. Therefore, the first 3 four-day average flow values of each month were disregarded.

The ratio of the low four-day average flow to the mean monthly flow was found. It was assumed that the ratio of the low four-day average to monthly mean flow was equivalent at Patterson and Crows Landing. Data from water years 1970-72 indicates that, in general, this assumption is valid (Table 5). This ratio was multiplied by $Q_{\text{Crows, Actual}}$ (from equation 7) to determine the monthly equivalent of the low four-day average flow at Crows Landing.

$$(9) \qquad \underset{\text{(monthly equivalent)}}{Q_{\text{Crows, 4-Day}}} = \frac{Q_{\text{Patterson, Low 4-day}}}{Q_{\text{Patterson, mean Monthly}}} \left(Q_{\text{Crows, Actual, (monthly)}} \right)$$

An example of this procedure is shown below:

February 1982

Patterson Low 4-Day Avg Flow	=	960 cfs
Patterson Mean Monthly Flow	=	2558 cfs
Calculated Crows Landing Monthly Flow	=	145,382 acre-ft

Crows Landing Monthly Equivalent of the Low Four-Day Average Flow

$$(10) \quad \frac{960 \text{ cfs}}{2558 \text{ cfs}} \quad (\ 145{,}382 \text{ acre-ft}\ ) \quad = \quad 54{,}538 \text{ acre-ft}$$

The flow record used for the TMML is presented in Table 6.

TMMLSJR MODEL STEPS

Once the flow record is established, the TMMLSJR model calculates an allowable load based on a set of user defined criteria. A schematic of the process is shown in Figure 8 and the detailed description follows.

Classification of Each Water Year

The TMMLSJR model recognizes the seasonal and year to year flow variations by dividing the historical flow record into various flow regimes. The first division is based on the water year.

Classification of water years in the San Joaquin River Basin is currently based on the Sacramento River Index (California State Water Resources Control Board, 1991a).

A classification system specifically for the San Joaquin River has been developed (California State Water Resources Control Board, 1991b), although it has not been formally adopted.

The San Joaquin River Index (SJR Index) is composed of the unimpaired runoff from the four major streams in the Basin:

Stanislaus River inflow to Melones Reservoir
Tuolumne River inflow to Don Pedro Reservoir
Merced River inflow to Exchequer Reservoir
San Joaquin River inflow to Millerton Reservoir

The index is determined as follows:

60 percent current year April-July runoff
20 percent current year October-March runoff
20 percent of the previous years index, not exceeding 0.9 million acre-ft.

$$\text{SJR Index} = 0.6(\text{Apr-Jul runoff}) + 0.2(\text{Oct-Mar runoff}) + 0.2(\text{previous year SJR Index}) \tag{11}$$

The water year classifications for the period considered are given in Table 7, along with the threshold values of the various classifications.

As will become evident later, the confidence one has in the design flow for each flow regime will be dependent on the amount of historical data for that flow regime. The more the historical data set is divided up into various flow regimes, the less data will be available in each flow regime. Therefore, instead of considering five water year types, the dry and below normal year types were combined as were the above normal and wet year types.

Since there were few water years in the Dry/Below Normal category from 1970-91, these year types could be combined with the critical water years. This is not done initially, since the Regional Board Basin Plan objectives make a distinction between a critical year and other year types.

Group Months by Time of Year

The second division of the flow record is based on seasons. Within a water year, there is a distinct seasonality in both the amount of flow in the San Joaquin and the drainage load (Fig. 4).

High drainage flows occur from February through August and high river flows occur from December through May. Recognizing this seasonality, the flow regimes within a water year can be divided into seasons which cover the combinations of high and low river flows and high and low drainage flows (Fig. 9). Incorporating this seasonality into the development of design flows allows the discharger to make the necessary adjustments to meet the load allocation for the particular season. In summary, the 264 monthly flow values for the 22-year period of record have been divided up into 12 flow regimes (Table 8) which reflect the combinations of four seasons and three water year groupings.

Determine an Acceptable Exceedance Rate

After the flow record is divided into the various flow regimes, a rate of violation of the objective is chosen and applied to the historical flow record. The US EPA criterion continuous concentration (chronic toxicity) is the four-day average concentration of a pollutant in water that should not be exceeded more than once every three years on average (U.S. EPA, 1986).

The US EPA recognizes that the nature of certain water quality problems is such that the goal of a one-in-three year exceedance rate cannot be met quickly; therefore, a phased reduction in loads is allowed. This phased load reduction can also be interpreted as a phased decrease in the exceedance rate. Several different exceedance rates will be evaluated, ranging from a one-in-five month rate to a one-in- three year rate.

These exceedance rates will be applied to the two different flow records; the monthly flow record and the monthly equivalent of the low four-day average flow.

Estimate Design Flow for Each Flow Regime

The first step in determining the design for each flow regime is to calculate the allowable number of violations, which can be found by multiplying the period of record by the allowable frequency of violation of objectives.

(12) Allowable No. of Violations = (Period of Record)(Allowable Frequency of Violation of Objectives)

For the 22-year record under consideration, the allowable number of violations for a one-in-three year exceedance rate is seven [(264 months) (1 Violation/36 months)] and for the one in five month rate is fifty-three [(264 months) (1 Violation/5 months)].

The simplest way of using this information to determine of the design flow is to use a method similar to the US EPA 7Q10 method. The flow record is rank-ordered from lowest to highest, and the eighth lowest flow is chosen as the design flow for the one in three year exceedance rate. If the TMML (Water Quality Objective multiplied by the Monthly Design Flow) calculated for the eighth lowest design flow is applied to the seven lower flows, a violation of the objective occurs. For all other flows (Rank 8-264), the objective is met.

Since the flow record has been divided up into twelve distinct flow regimes, the determination of designs flows for each regime is less straight forward than the standard US EPA 7Q10 method. The design flows chosen must still meet the criteria of allowable number of violations for the exceedance rate.

For the one-in-three year excursion rate scenario, there are seven allowable violations for the twelve flow regimes. This implies that the design flow for certain flow regimes will be the lowest flow (i.e., there can be no violations in that flow regime). It was assumed that the greatest difficulty in meeting objectives would occur in critical year types, therefore, more violations will be allowed to occur in critical years than wetter year types.

The procedure used is as follows:

1) The flows in each regime are rank ordered from the lowest to highest [see Tables 9(a - l) and 10(a - l)].

2) For the one in three year exceedance rate, initially, the tenth percentile flow (for the monthly objective) was chosen as the design flow for the critical year flow regimes. Since each flow regime contains a different number of data points, the percentile function is used to choose a consistent position within each distribution of flows.

3) The design flow chosen for all other flow regimes is the lowest flow, unless the lowest flow for a given season is less than the tenth percentile critical year design flow. If this is the case, the critical year design flow is used.

   For example, the tenth percentile flow for September through November of a critical year is 18,088 acre-ft and the lowest flow of an Above-Normal/Wet Year for the same season was 4,635 acre-ft; therefore, the design flow for the September-November, Above Normal/Wet flow regime is 18,088 acre-ft.

The percentile function with the Excel[tm] spreadsheet program was used to determine the design flow for each flow regime. As defined within Excel (Microsoft Excel, 1992; Hays, 1981), the percentile (K) of a given value in a rank order set of "n" values is a function of the rank "i" of the value.

$$K = \frac{i - 1}{n - 1} \tag{13}$$

For example, in the set {1.2, 1.8, 2.6, 3.6}, 1.8 is the 33rd percentile value. If the desired percentile is not an exact multiple of (1/n-1), then the value of the desired percentile is found by linear interpolation. In the example data set, the 30th percentile value would be 1.74.

The 30th percentile value lies between the 0th percentile value (1.2) and the 33rd percentile value (1.8). The rank "i" of the 30th percentile value is 1.9. The 30th percentile value "V" is:

$$\frac{2 - 1.9}{2 - 1} = \frac{1.8 - V}{1.8 - 1.2} \tag{14}$$

$$V = 1.74 \tag{15}$$

Determine Whether Actual Number of Violations Equals the Allowable Number of Violations

The first choice of percentile rank for each flow regime will not necessarily result in the number of violations allowed for a particular exceedance rate. The TMML is simply:

(16) TMML = (Design Flow)(Water Quality Objective)

Therefore, a violation will occur when the actual flow is less than the design flow. A count of the actual number of violations can be found by: 1) dividing the appropriate design flow by each data point within the flow regime; 2) counting the number of design flow to actual flow ratios greater than one. Each ratio greater than one will indicate a violation.

If the actual number of violations does not equal the desired number of violations, a new percentile rank is chosen.

The number of iterations required until the design flows produce the appropriate excursion rate is relatively few. A spreadsheet program with a percentile function and a database manager can be used to quickly determine design flows and "count" the number of violations.

Considering the one-in-three year exceedance rate of the monthly objective, the choice of the tenth percentile for critical year flows resulted in 12 violations. The fifth percentile resulted in 8 violations and the fourth percentile produced the desired number of violations (7).

For the scenarios evaluated, the percentiles chosen for each water year grouping which produced the desired number of violations are shown in Table 11. The design flows for each flow regime under each scenario are given in Table 12. The 5 µg/L objective was multiplied by the design flows under each scenario to determine the TMML. The TMML for each flow regime and scenario is shown in Table 13. The results of applying the calculated TMMLs to the historic flow record are shown in Table 14.

Allocate Load

The TMML represents the total load the stream system can assimilate.

When addressing non-point sources that are to be regulated, a redefinition of load allocation (LA) and waste load allocation (WLA) is appropriate (p. 5). The standard US EPA definition makes a distinction between point (WLA) and non-point sources and background (LA) (US EPA, 1986). When regulating some or all non-point sources, a more appropriate distinction to make is between regulated and non-regulated discharges.

Therefore, the TMML is divided into three components: (1) a load allocation (LA) for background and non-regulated discharges; (2) a waste load allocation (WLA) for the regulated discharge - point and non-point sources; (3) a margin of safety (MOS) which accounts for any data or methodological errors. In equation form:

(17) TMML = WLA + LA + MOS

1. Background

The load contributions from the Merced River and from the San Joaquin River at Lander Avenue (upstream of drainage inflow) were considered the background components. The concentration of the Merced River was assumed to be 0.2 μg/L (Westcot, *et al.*, 1990a) and the San Joaquin River at Lander Avenue, 0.5 μg/L (Karkoski and Tucker, 1993b).

The flow values from the same time period as the design flow were used. For example, in the February-May flow regime of a critical year, one in 3-year excursion rate, monthly objective (Table 10{g} and 12{a}), the design flow is closest to the flow which occurred on February 1991. Therefore, the February 1991 flows for the Merced River and San Joaquin Rivers at Lander Avenue are used to estimate background loads.

2. Margin of Safety

The margin of safety is included to account for any data or model deficiencies which might lead to an overestimate of the TMML. Data deficiencies are of the greatest concern when little is known about background contributions, and these contributions are potentially significant. Selenium sources are well-defined in this area, so such concerns are rather insignificant. A comparison of selenium load in Mud and Salt Sloughs with selenium load in the San Joaquin River at Crows Landing indicates almost all of the load is coming from the sloughs (Table 15a & b and Fig. 7).

Error is also inherent in the measurement of flow and water quality. Errors in individual water quality measurements by the CVRWQCB are 10% or less (Karkoski and Tucker, 1993 b). These errors would generally be of a random nature, so a greater amount of sampling would lead to a value closer to the population mean. Errors in flow measurement can be systematic due to miscalculation of channel geometry or an inexact rating curve. The Department of Water Resources rates its Patterson gauge as "good", which means the error is less than 10%. The error in the ratio used to convert the Patterson flow value to the Crows Landing flow value is also likely to be small (see pages 12-14).

The error in the methodology itself is difficult to quantify. It is assumed that by using historical flow data, estimates of future assimilative capacity can be made. If the "mix" of water year types is different in the future from the past 22 years, the assimilative capacity would differ. Significant changes in water management or rainfall could also affect the assimilative capacity in a given season.

The "mix" of water year types in the 1970-91 time frame is heavily weighted to critical years with 32% of the years classified as critical. In comparison, the 85-year period (1906-1990) upon which the San Joaquin River Index is based has 16% of its years classified as critical. The methodology, therefore, appears to have a built-in conservatism. If a more accurate reflection of the historical record (1906-1990) is desired, a Monte Carlo simulation could be developed which includes a stochastic component for Mud Slough (north) and Salt Slough.

It is anticipated that this methodology will be reviewed within three to five years of implementation, so corrections can be made if significant changes in water management have occurred.

The built-in conservatism of the methodology and the relative accuracy of the flow measurements imply that the margin of safety can be a small portion of the TMML or disregarded altogether. For the purposes of this report, a margin of safety of 10% of TMML was used.

3. Grassland Watershed Discharge

Once the background load and margin of safety have been determined, the remaining amount of assimilative capacity is allocated to the regulated discharge (WLA). With a 10% margin of safety:

$$(18) \qquad WLA = 0.9\ (TMML) - LA$$

Ideally, the WLA would be assigned to the last monitoring point prior to discharge into the San Joaquin River (i.e. Mud Slough (north) and Salt Slough - see Figures 1a & 1b). Allocation at this point would be possible if the Districts in the DSA agreed to be jointly responsible for the WLA. If such agreement does not occur, the WLA would have to be divided among the six districts and measured further upstream. Since the flow measuring devices at the District outlets are generally less accurate and calibrated less frequently than the gauges at the sloughs, the margin of safety may be increased (and the WLA decreased) to account for any measurement errors.

As has been noted previously, a possible "loss" of selenium is occurring between the district discharge points and the sloughs. If the measurement point of the WLA is moved from the sloughs to the District drains, no credit for this "loss" would be given unless the mechanism of this loss can be well defined and quantified.

An example of the basic spreadsheet used to calculate WLA is shown in Table 16. A summary of the WLAs for the various scenarios is given in Table 17.

DISCUSSION OF MODEL RESULTS, POSSIBLE REFINEMENTS, AND SENSITIVITY ANALYSIS

Model Results

A comparison of the annual WLA for various scenarios gives insight into the effect of varying the objective, the exceedance rate, and the methodology. Figure 10 summarizes the results of four scenarios. The first scenario represents the results of using a method similar to the US EPA 7Q10 method. This method makes no distinction between seasons or water year types - only one design flow is developed based on a one in three year exceedance rate. The second scenario uses the TMMLSJR methodology for the 4-day average objective and a one-in-three-year excursion rate. For the third scenario, the objective is based on a monthly mean, and in the fourth scenario, a one-in-five-month excursion rate is used.

The difference between Scenario One and Scenario Two demonstrates the benefit of the TMMLSJR model. By simply recognizing the variations in assimilative capacity between different year types, the amount of allowable load is increased significantly for Dry/Below-Normal years (100%) and Above-Normal/Wet years (107%). The allowable load for critical years is decreased by 7%.

Changing the averaging period from a 4-day averaging period to a monthly period increases the allowable load by 24% - 32%. A comparison of low 4-day flows within a month and the monthly mean flow (from Table 6) indicates that on average, the low 4-day average flow is 25% lower than the monthly mean flow. This is consistent with the observed changes in assimilative capacity.

The change in exceedance rate from once in three years (7 violations allowed) to once every five months (53 violations allowed) increases the annual allowable load by 60% - 120%.

It should be noted that a critical year relaxation in the concentration objective may not be necessary when using the TMMLSJR. Rather than relaxing the objective, a greater number of violations in the critical years could be allowed. As can be seen in Table 18, the 8 µg/L critical year relaxation is equivalent to changing the exceedance rate from one in three years to once in nineteen months.

As a check of the methodology, historical selenium loads were compared with calculated allowable loads. Allowable selenium loads for the water years 1986-1992 were tabulated (Table 19) along with the actual combined selenium loads from the sloughs and the actual monthly mean concentration at Crows Landing. A monthly mean 5 µg/L objective with a one-in-five month excursion rate was used to generate the allowable loads.

If the actual load equaled the allowable load for the period considered, the rate of violation of the objective would be once every five months. If the actual load **exceeds** the allowable load, it would be expected that the objective would be violated at a rate **greater** than once every five months. If the actual load is **less** than the allowable load, it would be expected that the objective would be violated at a rate of **less** than once every five months.

An analysis of Table 19 indicates that for the months in which the actual load was greater than the allowable load, the objective was violated 82% of the time. When the actual load was less than the allowable load, the rate of violation was 14%. The TMMLSJR model appears to be consistent with the observed data.

A comparison of water year 1989 and 1992[4] annual selenium loads from the sloughs with calculated annual allowable load indicates that slough loads are higher under most scenarios (Fig. 10). A more significant factor in determining the frequency of violation of objectives is the distribution of discharge for the year. A comparison of Figures 10 and 11 demonstrates the influence of the distribution of discharge. For the one-in-five month excursion rate, the actual annual load in WY 1992 (2975 lbs) is less than the annual allowable load (3939 lbs). One would expect a violation rate of less than once in five months, but since the distribution of discharge does not match the distribution of assimilative capacity, the violation rate is actually higher (once every three months).

A comparison of the monthly distribution of actual selenium loads from the sloughs with the allowable selenium load for various excursion rates is shown in Figures 12 and 13. These graphs indicate that in addition to implementation of drainage reduction strategies, the monthly distribution of drainage discharge may have to be altered.

Drainage reduction strategies suggested by the San Joaquin Valley Drainage Program (SJVDP, 1990) include: improved irrigation practices, agroforestry, use of groundwater in unconfined aquifer, and land retirement. The monthly distribution of discharge can be altered by increasing reuse of drainage and constructing reservoirs to regulate the drainage release.

Possible Model Refinements

The basic spreadsheet presented in Table 16 can be expanded to try to account for various factors that may affect the final waste load allocation to the districts in the DSA. Any expansion of the basic model inevitably introduces some amount of error. Therefore, the gain in comprehensiveness of the model must always be balanced against the amount of error introduced.

1. Wetland Contributions to the Selenium Load

Wetland water supplies can contain up to 2 μg/L of selenium. Water discharged from the wetlands flows into Mud Slough (north) and Salt Slough. If the wetland discharge is to be regulated, this load contribution could be part of the waste load allocation; otherwise, it would be a part of the background load. On average, current wetland discharges contain 1 μg/L selenium (CVRWQCB data, unpublished, 1993).

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[4] Water years were chosen to reflect pre-Basin Plan conditions (WY1989) and conditions due to drought and irrigation improvements (WY1992).

Estimates of monthly wetland discharges from Swain and Quinn were used to determine wetland loads. It was assumed that the discharge contained 1 μg/L selenium. The adjustments to the spreadsheet that were made to account for wetland discharges are shown in Table 20. The decrease in WLA for the DSA is between 0% and 15%, with an average decrease of 5%.

Although wetland flow estimates by Swain and Quinn are based largely on professional judgement, the significance of wetland discharge appears to warrant their inclusion in the background or WLA portions of the TMML. An alternative to specifying wetland discharges in the TMML would be to account for the discharges within the margin of safety. Since wetland loads are only potentially significant for certain months, the margin of safety could be selectively increased for just those months. Specific wetland flow and concentration values could be developed when more data becomes available.

2. Decreases in Design Flow Due to Drainage Reductions

The drainage water contributes a certain amount of flow to the San Joaquin River. When drainage is decreased, the flow in the San Joaquin River is decreased; and therefore, the total amount of assimilative capacity is decreased. The waste load allocation can be adjusted to account for this change in assimilative capacity.

The following equations allow determination of the adjusted WLA when drainage reduction is taken into account:

Q_D = Tile Drainage Flow
C_D = Tile Drainage Concentration
Q_R = Reduction in Tile Drainage Flow necessary to meet WLA
Q_F = Unadjusted Design Flow
C_O = Water Quality Objective
L_B = Background Load
L_{WET} = Wetland Load
L_{WLA} = Adjusted Waste Load Allocation
L_{TMML} = Adjusted TMML
MOS = Margin of Safety (0 to 1)

(19) $L_{WLA} = L_{TMML} - L_{WET} - L_B - L_{TMML} \times (MOS)$

Rearranging (19)

(20) $L_{WLA} = L_{TMML} (1 - MOS) - L_{WET} - L_B$

(21) $L_{TMML} = (Q_F - Q_R)\ C_O$

Substituting (21) into (20)

(22) $L_{WLA} = (Q_F - Q_R)\ C_O\ (1\text{-}MOS) - L_{WET} - L_B$

(23) $L_{WLA} = (Q_D - Q_R)\ C_D$

Setting (22) Equal to (23) and Rearranging

(24) $$Q_R = \frac{Q_D \times C_D + L_B + L_{WET} - Q_F\ (C_O)\ (1\text{-}MOS)}{C_D - C_O\ (1\text{-}MOS)}$$

The tile drainage concentration for the DSA was calculated by taking the mean of all tile sump data collected by the Regional Board (507 values). It was assumed that tail water would have essentially no selenium. The amount of tile drainage flow can then be calculated based on the total (tail and tile) drainage flow and load.

Q_T = Total Drainage Flow
C_T = Total Drainage Concentration
Q_{Tail} = Tail Water Flow
C_{Tail} = Tail Water Concentration

(25) $Q_T\ C_T = Q_{Tail}\ C_{Tail} + Q_D\ C_D$

(26) $Q_T = Q_{Tail} + Q_D$

Substituting (26) into (25) and Rearranging

(27) $$Q_R = \frac{Q_T\ (C_T - C_{Tail})}{(C_D - C_{Tail})}$$

If $C_{Tail} = 0$ or $C_{Tail} << C_T$ and C_D

(28) $$Q_R = \frac{Q_T\ C_T}{C_D}$$

An example spreadsheet which shows the results of this procedure is given in Table 21. The change in WLA is between 0% and 15% when reductions in assimilative capacity are taken into account. The average reduction in WLA is 4%.

The most significant argument against using the adjusted WLA is that the historic record upon which the design flows are derived did not include drainage water. As noted earlier, most of the drainage water was used to supplement wetland supplies prior to 1986. Use of drainage water for wetland supplies was legal until 1989. The highest drainage flows (February - August) corresponds with the highest rate of consumptive use (evapotranspiration) in the wetlands, so it is unlikely that much of the drainage water historically reached the San Joaquin River.

The discussion above argues strongly against adjusting the WLA based on drainage reduction. For other nonpoint source pollution problems in which the pollutant source contributes a significant portion of the total stream flow, such adjustments may be necessary.

Model Sensitivity Analysis

Significant management changes in the San Joaquin River could alter the hydrology of the River relative to the historic record. Adjustments in the design flow and major inputs can be made to account for these changes. Comparison of the historical Crows Landing flow values with the reconstructed flow data presented in the Swain-Quinn model gives an indication of the potential impact of current management practices on river hydrology. Recall that the Swain-Quinn model adjusted the historical flow record to account for current management of agricultural drainage flows. Reconstructed flows from the Swain-Quinn model, were found to be statistically similar to historic flows (Haith, 1992). The comparison considered paired flows in the 1968-90 time period.

It should be noted that the design flows presented for the TMMLSJR occur during low flows. Management changes may be statistically insignificant when the overall hydrology is considered, but may be statistically significant when low flow regimes are considered.

The same statistical techniques employed by Haith were used for all flows less than 57,000 acre feet[5]/month. Correlation between the two data sets is much poorer when only low flows are considered (Table 22). R^2 values found by Haith were 0.96 or greater, whereas R^2 values for low flow ranged between 0.354 and 0.904. A t-test on the monthly flows showed a statistically significant difference between the means for December and February through May at a 5% confidence interval. The comparison of low flows between the historic and adjusted record suggests management changes may impact assimilative capacity during critical periods.

Several potential management changes are analyzed relative to their impact on assimilative capacity. As irrigation efficiency is optimized, tail water discharge from the DSA may be eliminated. The method used to quantify tail water from the DSA is the same method used to quantify tile water (Equations 25-28). Results are given in Table 23. The decrease in WLA is between 2% and 46% when tail water elimination is taken into account with an average decrease of 11%.

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[5] 57,000 acre-feet is the highest design flow for the one in one year excursion rate. It is assumed that an excursion rate of greater than once a year would not be acceptable except as an interim target.

Wetland return flows may increase substantially due to the provisions in the Central Valley Project Improvement Act. This increase may provide greater flow in the River than was observed historically (since the supplies are generally from imported water). The wetland discharge estimates of Swain and Quinn were modified by adding an additional 36,000 acre-ft of return flow. These adjustments and related allowable load increases are shown in Table 24. Incorporating increased wetland flows results in an increase of between 4% and 46% with an average increase of 15%.

Other possible impacts include proposed US EPA EC objectives for the San Joaquin River which may require greater releases from eastside reservoirs in the April-May period than were made historically. The US EPA proposed electrical conductivity objectives are intended to protect spawning of striped bass in April and May. Release schedules from east side tributaries may be readjusted to provide additional flows during April and May. This adjustment would lead to less flow during other months. The results are presented in Table 25. The waste load allocation increases by 18% - 50% in April and May and decreases by 3% - 23% in other months.

POTENTIAL DIFFICULTIES IN IMPLEMENTATION OF WASTE LOAD ALLOCATIONS

Prediction of Water Year[6]

The allowable load for the DSA will vary depending on water year. The water year begins in October. The first prediction of the water year classification (for the Sacramento River index) does not occur until December 1st. The California Department of Water Resources publishes these predictions which are expressed as a probability of exceeding certain unimpaired flow values (Table 26). The water year designation is currently used to make management decisions for fish and wildlife purposes in addition to determining allocations for state and federal contractors. The first prediction of water year type for contract purposes is made in mid-February and the contract year begins in March.

The difficulties encountered in determining water year type (and, therefore, waste load allocation) are twofold for the first five months of the water year: 1) In October and November, when no prediction of unimpaired flow has been made, how is the appropriate waste load allocation to be determined? 2) When probabilities of unimpaired flow are developed (December-February), what is the appropriate choice of probability for predicting unimpaired flow?

Since the rainfall is generally minimal in October - December, the flow in the River will likely be dominated by reservoir operations. These operations will largely be determined by the amount of storage in the reservoir - i.e., the unimpaired flow from the previous water year. Therefore, the water year classification from the previous water year could be used to determine waste load allocations for October through December.

Justification for this approach can be found in the historic record. For example, in October through December of 1977, flow in the River was very low as a result of the drought of the previous water year, even though the water year (October 1977 - September 1978) was classified as a wet year.

Probabilities developed for unimpaired flow become more meaningful as the rainy season progresses. Early in the water year, the distribution of possible unimpaired flows will have a high standard deviation. Since little rain has fallen or little snow pack has developed, the range of possible unimpaired flows is great. As the rainy season progresses, the range of possible unimpaired flows also decreases.

To insure that unimpaired flow is not underpredicted early in the water year, a relatively low probability of exceedance could be chosen - such as 50% or 75%. As the water year progresses, a higher probability of exceedance could be chosen.

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[6] The discussion on the appropriate classification for months early in the water year was aided substantially by M. Roos, California Department of Water Resources.

The discussion above argues for a different definition of water year as it relates to instream flow. Changing the water year definition from October-September to January-December results in a smaller distribution of flows (i.e. the standard deviation of each water year group decreased when the water year was redefined (Table 27a)). This decrease in standard deviation suggests that the January-December water year definition is the more appropriate definition when considering flows downstream of major reservoirs.

Changing the definition of water year classification also changes the TMML (Table 27b). The annual TMML decreased by 146 pounds for critical years and increased by 1,260 pounds for above-normal and wet years. Redefinition of the water year appears to be both appropriate and will facilitate implementation of load allocations.

Determining Compliance with WLAs

Determining compliance with waste load allocations will inevitably take place after the discharge has occurred. The standard turn around time for selenium analysis is three to four weeks. An individual district or regional drainage entity may want to have a real time estimate of compliance in order to modify operations. Such an estimate can be made by correlating electrical conductivity with selenium concentration.

For the Panoche Drainage District, this correlation works well for the irrigation season - $R^2 = 0.66$ (Figure 14a), but the correlation is poor for the nonirrigation season - $R^2 = 0.09$ (Figure 14b)[7]. During the irrigation season, the quality of water in the district surface drain is dependent on the amount of tail water and the quality of the integrated mixture of tile water. During the nonirrigation season, the surface drain quality is largely dependent on the quality of the few tile sumps that discharge periodically. The quality in the nonirrigation season will show a greater variation as single sumps switch on and off.

Rather than use an EC to selenium correlation during the nonirrigation season, a constant selenium concentration value can be assumed. A value with a low probability of being exceeded could be chosen. For the Panoche Drain, ninety-five percent of the data during the nonirrigation season were less than 120 µg/l and ninety percent of the data were less than 109 µg/l. Making a conservative assumption regarding concentration would ensure that waste load allocations would not be exceeded.

A third alternative suggested by Haith (personal communication, 1994) is to increase the frequency of sampling and reduce the processing time for analysis. The turn around time for selenium analysis can be reduced to seven to twelve days for at a slightly greater cost ($20 vs. $14 per sample). This alternative is practical if the daily variability of selenium concentration is low. Limited data for the irrigation season (Thomasson and Cooper, 1989) indicates that this variability is low, but more analysis should be performed before this alternative is implemented.

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[7] Data from Karkoski and Tucker, 1993 a; Westcot, et al., 1992, 1991, 1990b; and James, et al., 1988.

CONCLUSION AND RECOMMENDATIONS

The TMMLSJR model appears to be the most appropriate for developing regulatory load limits in the San Joaquin River downstream of the Merced River. The recognition of varying assimilative capacity between year types and within water years provides flexibility for the discharger by allowing a greater allowable discharge without increasing the frequency of violation of objectives.

The use of a simple spreadsheet model is justified, since the basic model relies on data which has relatively little error. As the spreadsheet is expanded to account for other factors, such as wetland load contributions or future management changes, the reliability of the model decreases as additional error is introduced. More data and/or a more sophisticated model may be required if more factors are to be taken into account in developing waste load allocations.

Wetland load contributions may be significant at times. The work performed by Swain and Quinn in estimating wetland flows should be expanded and updated in order to develop an historic record of wetland releases. In its current form, the accuracy of the current wetland flow estimates does not warrant their inclusion in the TMMLSJR model.

The final waste load allocation target will depend on the exceedance rate and the averaging period. Careful consideration should be given to the particular physiological effects of selenium when choosing an exceedance rate and averaging period which will be protective of the aquatic environment. Higher exceedance rates can be used to develop interim load targets.

Successful implementation of the waste load allocation targets hinges on the ability to predict the water year type and measure the quantity of pollutant discharged on a real time basis. Prediction of water year type can be enhanced by defining the water year based on the calendar year rather than October-September. This redefinition of water year is appropriate when considering yearly differences in river hydrology rather than yearly differences in precipitation.

In summary, the TMMLSJR model adequately characterizes the assimilative capacity of the San Joaquin River and can be used to develop waste load allocations for the DSA. Any uncertainties in the model can be addressed by periodically reviewing and updating the model as more data becomes available.

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TABLE 1

Major Districts in the Drainage Study Area (DSA)
on the West Side of the San Joaquin Valley

District	Acres	Approx. Tiled Area
Broadview Water District	9,515	7,410
Central California Irrigation District (CCID)	6,000	1,580
Charleston Drainage District	4,314	1,100
Firebaugh Canal Water District	22,640	9,220
Pacheco Water District	5,851	3,550
Panoche Drainage District	42,300	22,000
Total	90,620	44,860

From State Water Resources Control Board, 1987
and Central Valley Regional Water Quality Control
Board Data.

TABLE 2

Selenium Water Quality Objectives as Adopted by the State Water Resources Control Board for the San Joaquin River Basin (5C)

Water Body	Monthly Mean Objective (µg/l)	Compliance Date
San Joaquin River, mouth of the Merced River to Vernalis (Delta Inflow)	5 8*	Oct. 1, 1991
Salt Slough, Mud Slough (north), San Joaquin River, Sack Dam to mouth of the Merced River	10	Oct. 1, 1993
Wetland water supplies	2	Oct. 1, 1989

* Critical water year objective

TABLE 3

Comparison of Monthly Flow Data (Acre-Ft) from Water Years 1970-1972 for Three Sites on the San Joaquin River Downstream of the Merced River and Upstream of the Tuolumne River: Hills Ferry (HF), Crows Landing (CL), Patterson (PAT)

Date	HF 1	CL 2	PAT 3	(CL)-(PAT) (2)-(3) 4	(CL)-(HF) (2)-(1) 5	CL/PAT (2)/(3) 6	CL/HF (2)/(1) 7
Oct-69	90,530	89,850	96,590	-6,740	-680	93%	99%
Nov-69	110,400	110,700	121,700	-11,000	300	91%	100%
Dec-69	105,500	105,900	112,900	-7,000	400	94%	100%
Jan-70	177,800	174,500	180,000	-5,500	-3,300	97%	98%
Feb-70	161,500	168,600	167,000	1,600	7,100	101%	104%
Mar-70	143,600	148,500	151,800	-3,300	4,900	98%	103%
Apr-70	44,340	47,800	57,480	-9,680	3,460	83%	108%
May-70	35,700	39,870	48,670	-8,800	4,170	82%	112%
Jun-70	22,200	27,090	29,070	-1,980	4,890	93%	122%
Jul-70	18,500	23,000	23,360	-360	4,500	98%	124%
Aug-70	21,180	26,310	27,760	-1,450	5,130	95%	124%
Sep-70	24,640	31,180	34,500	-3,320	6,540	90%	127%
Oct-70	23,490	28,400	33,960	-5,560	4,910	84%	121%
Nov-70	32,560	35,570	37,170	-1,600	3,010	96%	109%
Dec-70	84,750	87,560	94,060	-6,500	2,810	93%	103%
Jan-71	68,950	72,530	83,170	-10,640	3,580	87%	105%
Feb-71	46,000	51,030	53,080	-2,050	5,030	96%	111%
Mar-71	40,380	49,910	50,150	-240	9,530	100%	124%
Apr-71	34,980	44,860	45,750	-890	9,880	98%	128%
May-71	32,920	41,320	43,870	-2,550	8,400	94%	126%
Jun-71	25,440	32,470	31,080	1,390	7,030	104%	128%
Jul-71	18,070	22,820	22,700	120	4,750	101%	126%
Aug-71	16,840	20,320	21,590	-1,270	3,480	94%	121%
Sep-71	20,600	23,660	29,610	-5,950	3,060	80%	115%
Oct-71	29,380	31,380	36,800	-5,420	2,000	85%	107%
Nov-71	24,750	27,480	29,100	-1,620	2,730	94%	111%
Dec-71	28,890	32,510	35,120	-2,610	3,620	93%	113%
Jan-72	70,630	72,850	72,750	100	2,220	100%	103%
Feb-72	56,840	61,890	59,890	2,000	5,050	103%	109%
Mar-72	29,580	35,030	30,170	4,860	5,450	116%	118%
Apr-72	21,550	27,470	26,100	1,370	5,920	105%	127%
May-72	16,930	21,500	19,940	1,560	4,570	108%	127%
Jun-72	13,500	16,500	15,490	1,010	3,000	107%	122%
Jul-72	12,720	16,000	14,690	1,310	3,280	109%	126%
Aug-72	15,200	19,510	20,790	-1,280	4,310	94%	128%
Sep-72	63,580	69,230	76,920	-7,690	5,650	90%	109%
				Avg (4)	Avg(5)	Avg(6)	Avg(7)
Avg. Difference in Flow				-2,769	4,186	96%	115%
				Avg(|4|)	Avg(|5|)		
Avg. Absolute Difference in Flow				3,620	4,407		

TABLE 4

SJRIO-2 Model Calculated Flow Values for the Crows Landing (Crows) and Patterson Sites on the San Joaquin River

Date	Crows	Patterson	Crw/Pat
Oct-76	34,702	37,778	92%
Nov-76	32,321	32,418	100%
Dec-76	23,634	23,695	100%
Jan-77	31,227	31,310	100%
Feb-77	28,270	28,222	100%
Mar-77	21,774	21,440	102%
Apr-77	11,797	13,024	91%
May-77	14,615	17,349	84%
Jun-77	4,904	6,688	73%
Jul-77	6,534	7,859	83%
Aug-77	7,254	9,699	75%
Sep-77	3,389	5,690	60%
Oct-77	5,162	6,024	86%
Nov-77	13,073	12,995	101%
Dec-77	15,559	15,605	100%
Jan-78	91,031	91,182	100%
Feb-78	310,345	310,611	100%
Mar-78	520,383	520,772	100%
Apr-78	883,487	884,666	100%
May-78	617,758	618,526	100%
Jun-78	183,447	185,917	99%
Jul-78	46,726	52,349	89%
Aug-78	44,464	49,084	91%
Sep-78	94,508	99,039	95%
Oct-78	106,387	109,392	97%
Nov-78	88,727	88,996	100%
Dec-78	53,679	53,965	99%
Jan-79	121,077	121,154	100%
Feb-79	173,139	173,313	100%
Mar-79	219,574	219,806	100%
Apr-79	80,168	83,753	96%
May-79	64,370	69,130	93%
Jun-79	56,627	62,705	90%
Jul-79	44,236	51,024	87%
Aug-79	34,895	40,202	87%
Sep-79	45,980	54,822	84%
Oct-79	58,849	62,339	94%
Nov-79	46,581	46,669	100%
Dec-79	45,975	46,058	100%
Jan-80	380,958	380,981	100%
Feb-80	572,327	572,524	100%
Mar-80	891,085	891,751	100%
Apr-80	201,553	212,683	95%
May-80	227,838	239,539	95%
Jun-80	85,826	97,605	88%
Jul-80	79,692	90,012	89%
Aug-80	47,136	58,566	80%
Sep-80	85,503	97,929	87%
Oct-80	77,157	84,496	91%
Nov-80	59,184	59,191	100%
Dec-80	53,496	53,588	100%
Jan-81	56,264	56,399	100%
Feb-81	56,108	56,352	100%
Mar-81	84,521	84,710	100%
Apr-81	48,599	54,499	89%
May-81	49,140	55,452	89%
Jun-81	34,258	39,368	87%
Jul-81	34,116	39,565	86%
Aug-81	36,472	42,366	86%
Sep-81	30,631	36,499	84%

Date	Crows	Patterson	Crw/Pat
Oct-81	31,191	33,606	93%
Nov-81	36,482	36,673	99%
Dec-81	41,766	41,817	100%
Jan-82	91,302	91,472	100%
Feb-82	147,387	147,628	100%
Mar-82	230,730	231,169	100%
Apr-82	907,329	910,463	100%
May-82	606,512	609,374	100%
Jun-82	163,920	168,292	97%
Jul-82	116,365	120,829	96%
Aug-82	72,225	78,581	92%
Sep-82	100,490	106,203	95%
Oct-82	151,612	154,465	98%
Nov-82	217,993	218,206	100%
Dec-82	749,882	750,043	100%
Jan-83	802,721	802,899	100%
Feb-83	1,194,371	1,194,611	100%
Mar-83	1,590,604	1,591,014	100%
Apr-83	1,120,895	1,124,848	100%
May-83	863,116	868,745	99%
Jun-83	938,804	942,926	100%
Jul-83	700,547	703,322	100%
Aug-83	160,576	165,568	97%
Sep-83	233,057	238,633	98%
Oct-83	367,604	371,119	99%
Nov-83	249,900	250,067	100%
Dec-83	516,097	516,267	100%
Jan-84	739,525	739,536	100%
Feb-84	155,807	155,904	100%
Mar-84	91,086	93,375	98%
Apr-84	75,878	81,137	94%
May-84	62,778	67,740	93%
Jun-84	60,443	66,583	91%
Jul-84	51,296	56,193	91%
Aug-84	53,220	59,566	89%
Sep-84	49,933	55,214	90%
Oct-84	63,871	67,070	95%
Nov-84	55,485	55,529	100%
Dec-84	98,803	98,830	100%
Jan-85	69,283	69,338	100%
Feb-85	51,877	51,993	100%
Mar-85	67,775	71,088	95%
Apr-85	63,041	68,119	93%
May-85	55,818	60,442	92%
Jun-85	46,873	52,115	90%
Jul-85	45,604	50,092	91%
Aug-85	45,356	52,508	86%
Sep-85	46,306	53,508	87%
Oct-85	46,412	49,492	94%
Nov-85	35,499	35,772	99%
Dec-85	49,526	49,725	100%
Jan-86	41,139	41,306	100%
Feb-86	211,267	213,057	99%
Mar-86	928,196	928,861	100%
Apr-86	611,549	614,722	99%
May-86	216,521	223,032	97%
Jun-86	125,604	132,385	95%
Jul-86	68,375	75,016	91%
Aug-86	68,339	74,980	91%
Sep-86	68,843	74,546	92%

Date	Crows	Patterson	Crw/Pat
Oct-86	67,417	70,270	96%
Nov-86	39,927	40,244	99%
Dec-86	35,528	35,662	100%
Jan-87	41,362	41,647	99%
Feb-87	46,580	47,361	98%
Mar-87	70,899	71,404	99%
Apr-87	44,996	51,101	88%
May-87	43,766	49,956	88%
Jun-87	43,796	49,078	89%
Jul-87	43,438	48,430	90%
Aug-87	43,970	50,492	87%
Sep-87	36,821	42,421	87%
Oct-87	30,230	34,341	88%
Nov-87	40,442	40,782	99%
Dec-87	34,222	34,390	100%
Jan-88	44,061	44,327	99%
Feb-88	42,271	43,319	98%
Mar-88	51,209	52,732	97%
Apr-88	45,182	47,933	94%
May-88	41,188	44,166	93%
Jun-88	38,732	41,566	93%
Jul-88	35,462	38,413	92%
Aug-88	38,952	42,676	91%
Sep-88	28,516	32,312	88%
Oct-88	24,294	26,089	93%
Nov-88	24,917	26,056	96%
Dec-88	29,024	29,772	97%
Jan-89	32,218	32,345	100%
Feb-89	30,400	30,610	99%
Mar-89	43,463	43,701	99%
Apr-89	47,537	49,798	95%
May-89	38,416	41,045	94%
Jun-89	30,339	32,671	93%
Jul-89	30,018	32,810	91%
Aug-89	32,854	36,836	89%
Sep-89	25,438	29,279	87%
Oct-89	28,008	29,739	94%
Nov-89	33,436	33,512	100%
Dec-89	34,391	34,491	100%
Jan-90	30,657	30,757	100%
Feb-90	34,720	35,074	99%
Mar-90	33,588	33,893	99%
Apr-90	29,501	32,681	90%
May-90	27,066	29,742	91%
Jun-90	22,109	24,920	89%
Jul-90	27,100	30,270	90%
Aug-90	26,664	29,788	90%
Sep-90	18,911	21,890	86%
Oct-90	16,306	18,030	90%
Nov-90	17,994	18,756	96%
Dec-90	17,757	18,645	95%
Jan-91	14,477	15,165	95%
Feb-91	12,933	14,617	88%
Mar-91	55,692	56,474	99%
Apr-91	28,867	31,773	91%
May-91	19,529	22,336	87%
Jun-91	12,736	15,260	83%
Jul-91	15,190	17,717	86%
Aug-91	16,363	19,510	84%
Sep-91	12,430	15,294	81%

TABLE 5

Comparison of Crows Landing and Patterson Sites on the San Joaquin River;
Low 4-Day Average Flow to Monthly Mean Ratios

Month	Patterson Low 4-Day Flow/ Monthly Avg 1	Crows Low 4-Day Flow/ Monthly Avg 2	Percent Difference (1-2)/2 3
Oct-69	0.66	0.66	1%
Nov-69	0.84	0.82	2%
Dec-69	0.75	0.72	4%
Jan-70	0.53	0.53	1%
Feb-70	0.72	0.69	4%
Mar-70	0.42	0.36	18%
Apr-70	0.92	0.92	0%
May-70	0.71	0.77	-8%
Jun-70	0.90	0.89	1%
Jul-70	0.82	0.89	-8%
Aug-70	0.83	0.86	-4%
Sep-70	0.86	0.94	-8%
Oct-70	0.80	0.80	0%
Nov-70	0.75	0.74	1%
Dec-70	0.71	0.68	4%
Jan-71	0.83	0.80	4%
Feb-71	0.76	0.82	-7%
Mar-71	0.85	0.85	0%
Apr-71	0.78	0.76	4%
May-71	0.83	0.83	0%
Jun-71	0.78	0.80	-2%
Jul-71	0.87	0.88	-1%
Aug-71	0.89	0.91	-2%
Sep-71	0.88	0.95	-8%
Oct-71	0.74	0.79	-6%
Nov-71	0.82	0.80	2%
Dec-71	0.84	0.79	6%
Jan-72	0.63	0.57	11%
Feb-72	0.49	0.51	-3%
Mar-72	0.80	0.81	-1%
Apr-72	0.62	0.80	-22%
May-72	0.81	0.86	-6%
Jun-72	0.85	0.85	0%
Jul-72	0.71	0.82	-13%
Aug-72	0.76	0.83	-8%
Sep-72	0.29	0.29	0%

Average Difference	Avg(3)	-1%
Avg Absolute Difference	Avg(|3|)	5%

TABLE 6

Actual and Calculated Flow Record for the San Joaquin River at Crows Landing (Water Years 1970-1991)
Flow in Acre-Ft/Month

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
AN	Oct-69			89,850	0.66	59,154
AN	Nov-69			110,700	0.82	90,613
AN	Dec-69			105,900	0.72	76,246
AN	Jan-70			174,500	0.53	91,788
AN	Feb-70			168,600	0.69	116,632
AN	Mar-70			148,500	0.36	53,155
AN	Apr-70			47,800	0.92	44,029
AN	May-70			39,870	0.77	30,869
AN	Jun-70			27,090	0.89	23,978
AN	Jul-70			23,000	0.89	20,441
AN	Aug-70			26,310	0.86	22,748
AN	Sep-70			31,180	0.94	29,220
BN	Oct-70			28,400	0.80	22,757
BN	Nov-70			35,570	0.74	26,389
BN	Dec-70			87,560	0.68	59,258
BN	Jan-71			72,530	0.80	58,071
BN	Feb-71			51,030	0.82	41,753
BN	Mar-71			49,910	0.85	42,346
BN	Apr-71			44,860	0.76	33,934
BN	May-71			41,320	0.83	34,298
BN	Jun-71			32,470	0.80	25,947
BN	Jul-71			22,820	0.88	20,014
BN	Aug-71			20,320	0.91	18,449
BN	Sep-71			23,660	0.95	22,535
D	Oct-71			31,380	0.79	24,747
D	Nov-71			27,480	0.80	22,105
D	Dec-71			32,510	0.79	25,822
D	Jan-72			72,850	0.57	41,537
D	Feb-72			61,890	0.51	31,537
D	Mar-72			35,030	0.81	28,343
D	Apr-72			27,470	0.80	22,060
D	May-72			21,500	0.86	18,555
D	Jun-72			16,500	0.85	14,085
D	Jul-72			16,000	0.82	13,175
D	Aug-72			19,510	0.83	16,112
D	Sep-72			69,230	0.29	20,202
AN	Oct-72	68,020	0.97	66,151	0.61	40,139
AN	Nov-72	60,170	1.00	59,988	0.54	32,513
AN	Dec-72	51,920	0.99	51,645	0.85	44,023
AN	Jan-73	93,080	1.00	93,021	0.38	35,395
AN	Feb-73	261,600	1.00	261,337	0.31	79,736
AN	Mar-73	211,500	1.00	211,277	0.60	126,201
AN	Apr-73	103,800	0.96	99,357	0.60	59,392
AN	May-73	58,350	0.93	54,332	0.87	47,521
AN	Jun-73	40,830	0.90	36,872	0.92	33,878
AN	Jul-73	37,470	0.87	32,485	0.89	28,809
AN	Aug-73	40,710	0.87	35,336	0.90	31,973
AN	Sep-73	51,190	0.84	42,934	0.90	38,719

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
W	Oct-73	64,030	0.94	60,045	0.88	52,681
W	Nov-73	66,780	0.99	66,270	0.67	44,524
W	Dec-73	80,970	1.00	80,646	0.77	62,219
W	Jan-74	187,900	1.00	187,140	0.83	156,181
W	Feb-74	92,770	0.99	91,991	0.61	56,174
W	Mar-74	101,400	1.00	101,327	0.70	70,691
W	Apr-74	111,800	0.99	111,223	0.67	74,905
W	May-74	82,120	0.97	79,723	0.81	64,770
W	Jun-74	83,410	0.95	79,138	0.59	46,917
W	Jul-74	47,570	0.91	43,359	0.85	36,943
W	Aug-74	45,310	0.91	41,297	0.89	36,810
W	Sep-74	52,520	0.92	48,502	0.82	39,638
W	Oct-74	59,290	0.94	55,600	0.86	48,014
W	Nov-74	72,910	0.99	72,354	0.90	65,101
W	Dec-74	69,110	1.00	68,833	0.79	54,046
W	Jan-75	60,970	1.00	60,723	0.84	51,198
W	Feb-75	151,900	0.99	150,624	0.52	78,489
W	Mar-75	135,800	1.00	135,703	0.56	75,725
W	Apr-75	125,000	0.99	124,355	0.68	84,370
W	May-75	79,920	0.97	77,587	0.78	60,879
W	Jun-75	129,000	0.95	122,392	0.60	73,718
W	Jul-75	55,280	0.91	50,386	0.83	42,046
W	Aug-75	58,980	0.91	53,756	0.80	43,223
W	Sep-75	84,790	0.92	78,303	0.80	62,643
C	Oct-75	102,800	0.96	98,626	0.55	53,968
C	Nov-75	58,460	0.99	58,000	0.95	55,272
C	Dec-75	50,380	1.00	50,191	0.90	45,278
C	Jan-76	41,650	0.99	41,365	0.90	37,269
C	Feb-76	44,400	0.98	43,668	0.86	37,724
C	Mar-76	46,090	0.99	45,764	0.79	36,091
C	Apr-76	44,180	0.88	38,902	0.82	31,955
C	May-76	37,650	0.88	32,985	0.74	24,430
C	Jun-76	33,860	0.89	30,216	0.90	27,072
C	Jul-76	30,480	0.90	27,338	0.88	24,186
C	Aug-76	43,150	0.87	37,576	0.80	30,167
C	Sep-76	43,930	0.87	38,131	0.81	31,057
C	Oct-76	41,940	0.92	38,525	0.78	29,922
C	Nov-76	33,310	1.00	33,210	0.85	28,070
C	Dec-76	26,030	1.00	25,963	0.96	24,977
C	Jan-77	34,760	1.00	34,668	0.86	29,648
C	Feb-77	26,260	1.00	26,305	0.68	17,772
C	Mar-77	21,750	1.02	22,089	0.55	12,223
C	Apr-77	14,450	0.91	13,089	0.39	5,066
C	May-77	19,220	0.84	16,191	0.57	9,272
C	Jun-77	6,803	0.73	4,988	0.67	3,338
C	Jul-77	7,738	0.83	6,433	0.87	5,611
C	Aug-77	10,370	0.75	7,756	0.81	6,314
C	Sep-77	6,143	0.60	3,659	0.76	2,764

TABLE 6

Actual and Calculated Flow Record for the San Joaquin River at Crows Landing (Water Years 1970-1991)
Flow in Acre-Ft/Month

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
W	Oct-77	5,409	0.86	4,635	0.76	3,517
W	Nov-77	11,830	1.01	11,901	0.45	5,345
W	Dec-77	15,450	1.00	15,404	0.77	11,817
W	Jan-78	82,920	1.00	82,783	0.23	19,260
W	Feb-78	291,400	1.00	291,150	0.13	38,137
W	Mar-78	534,800	1.00	534,401	0.25	136,246
W	Apr-78	865,500	1.00	864,347	0.68	584,735
W	May-78	632,600	1.00	631,815	0.55	346,059
W	Jun-78	206,400	0.99	203,658	0.52	106,125
W	Jul-78	58,110	0.89	51,868	0.81	42,190
W	Aug-78	54,430	0.91	49,307	0.87	42,944
W	Sep-78	109,000	0.95	104,013	0.66	68,440
AN	Oct-78	117,300	0.97	114,078	0.83	94,496
AN	Nov-78	98,810	1.00	98,511	0.57	56,124
AN	Dec-78	59,940	0.99	59,622	0.86	51,561
AN	Jan-79	112,500	1.00	112,429	0.37	41,996
AN	Feb-79	157,700	1.00	157,542	0.45	70,727
AN	Mar-79	225,700	1.00	225,462	0.63	142,307
AN	Apr-79	92,990	0.96	89,010	0.68	60,235
AN	May-79	76,740	0.93	71,456	0.82	58,828
AN	Jun-79	69,580	0.90	62,836	0.69	43,438
AN	Jul-79	56,590	0.87	49,062	0.91	44,442
AN	Aug-79	44,620	0.87	38,730	0.70	27,117
AN	Sep-79	50,430	0.84	42,296	0.64	26,979
W	Oct-79	69,210	0.94	65,335	0.61	40,037
W	Nov-79	51,800	1.00	51,702	0.78	40,285
W	Dec-79	51,110	1.00	51,018	0.87	44,619
W	Jan-80	346,600	1.00	346,579	0.17	57,939
W	Feb-80	569,300	1.00	569,104	0.25	139,733
W	Mar-80	908,200	1.00	907,522	0.52	470,023
W	Apr-80	236,000	0.95	223,650	0.88	197,637
W	May-80	255,600	0.95	243,114	0.69	168,170
W	Jun-80	108,400	0.88	95,318	0.72	68,165
W	Jul-80	99,960	0.89	88,499	0.58	51,542
W	Aug-80	64,960	0.80	52,282	0.70	36,486
W	Sep-80	104,600	0.87	91,328	0.87	79,758
D	Oct-80	93,860	0.91	85,708	0.61	51,993
D	Nov-80	60,660	1.00	60,653	0.77	46,778
D	Dec-80	58,730	1.00	58,629	0.92	54,000
D	Jan-81	61,650	1.00	61,502	0.70	43,170
D	Feb-81	62,540	1.00	62,269	0.77	47,748
D	Mar-81	87,130	1.00	86,936	0.68	58,698
D	Apr-81	60,550	0.89	53,995	0.79	42,716
D	May-81	61,550	0.89	54,544	0.94	51,453
D	Jun-81	43,690	0.87	38,019	0.75	28,633
D	Jul-81	43,920	0.86	37,871	0.93	35,354
D	Aug-81	47,040	0.86	40,496	0.95	38,282
D	Sep-81	40,500	0.84	33,989	0.95	32,336

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
W	Oct-81	37,247	0.93	34,570	0.73	25,388
W	Nov-81	40,734	0.99	40,522	0.63	25,557
W	Dec-81	46,355	1.00	46,298	0.86	40,032
W	Jan-82	101,508	1.00	101,319	0.70	71,193
W	Feb-82	145,620	1.00	145,382	0.38	54,538
W	Mar-82	237,203	1.00	236,753	0.74	174,907
W	Apr-82	852,991	1.00	850,055	0.44	372,573
W	May-82	670,234	1.00	667,086	0.48	320,222
W	Jun-82	186,823	0.97	181,970	0.66	120,860
W	Jul-82	134,221	0.96	129,262	0.70	89,860
W	Aug-82	87,133	0.92	80,085	0.94	75,446
W	Sep-82	117,778	0.95	111,442	0.80	89,662
W	Oct-82	170,080	0.98	166,939	0.90	150,123
W	Nov-82	198,550	1.00	198,356	0.58	114,585
W	Dec-82	685,010	1.00	684,863	0.67	459,059
W	Jan-83	780,560	1.00	780,387	0.53	412,800
W	Feb-83	1,261,690	1.00	1,261,437	0.72	910,630
W	Mar-83	1,567,540	1.00	1,567,136	0.95	1,487,619
W	Apr-83	1,145,650	1.00	1,141,624	0.90	1,031,731
W	May-83	877,090	0.99	871,407	0.80	693,362
W	Jun-83	946,510	1.00	942,372	0.95	896,063
W	Jul-83	763,580	1.00	760,567	0.29	224,311
W	Aug-83	183,850	0.97	178,307	0.85	151,173
W	Sep-83	259,640	0.98	253,573	0.87	221,562
AN	Oct-83	378,090	0.99	374,509	0.78	293,747
AN	Nov-83	275,740	1.00	275,556	0.79	217,043
AN	Dec-83	472,460	1.00	472,304	0.60	283,363
AN	Jan-84	733,470	1.00	733,459	0.50	370,151
AN	Feb-84	164,890	1.00	164,787	0.77	127,364
AN	Mar-84	103,720	0.98	101,177	0.84	85,326
AN	Apr-84	90,150	0.94	84,307	0.88	74,429
AN	May-84	75,110	0.93	69,608	0.89	61,824
AN	Jun-84	73,850	0.91	67,040	0.85	57,016
AN	Jul-84	62,260	0.91	56,834	0.89	50,820
AN	Aug-84	66,150	0.89	59,103	0.87	51,610
AN	Sep-84	61,180	0.90	55,328	0.94	51,887
D	Oct-84	74,380	0.95	70,832	0.82	57,852
D	Nov-84	57,015	1.00	56,970	0.76	43,404
D	Dec-84	97,111	1.00	97,084	0.87	84,369
D	Jan-85	71,153	1.00	71,097	0.80	56,908
D	Feb-85	51,971	1.00	51,855	0.88	45,384
D	Mar-85	76,443	0.95	72,880	0.65	47,132
D	Apr-85	75,570	0.93	69,937	0.91	63,328
D	May-85	67,029	0.92	61,901	0.92	57,181
D	Jun-85	57,709	0.90	51,904	0.68	35,554
D	Jul-85	55,511	0.91	50,537	0.91	46,196
D	Aug-85	58,151	0.86	50,230	0.90	44,973
D	Sep-85	59,338	0.87	51,351	0.91	46,526

TABLE 6

Actual and Calculated Flow Record for the San Joaquin River at Crows Landing (Water Years 1970-1991)
Flow in Acre-Ft/Month

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
W	Oct-85	54,895	0.94	51,479	0.86	44,313
W	Nov-85	39,703	0.99	39,400	0.92	36,212
W	Dec-85	55,214	1.00	54,993	0.77	42,150
W	Jan-86	45,824	1.00	45,639	0.91	41,489
W	Feb-86	278,882	0.99	276,539	0.18	50,692
W	Mar-86	876,040	1.00	875,413	0.43	379,568
W	Apr-86	682,969	0.99	679,444	0.60	407,424
W	May-86	247,636	0.97	240,407	0.65	156,245
W	Jun-86	147,094	0.95	139,560	0.62	86,801
W	Jul-86	83,127	0.91	75,768	0.84	63,750
W	Aug-86	83,226	0.91	75,855	0.95	71,873
W	Sep-86	82,790	0.92	76,456	0.83	63,744
C	Oct-86	78,060	0.96	74,891	0.83	62,015
C	Nov-86	44,666	0.99	44,314	0.90	39,702
C	Dec-86	39,594	1.00	39,445	0.95	37,290
C	Jan-87	46,260	0.99	45,943	0.86	39,693
C	Feb-87	52,616	0.98	51,748	0.82	42,501
C	Mar-87	79,305	0.99	78,744	0.59	46,572
C	Apr-87	56,771	0.88	49,989	0.89	44,601
C	May-87	55,500	0.88	48,623	0.92	44,552
C	Jun-87	54,500	0.89	48,634	0.92	44,562
C	Jul-87	53,752	0.90	48,211	0.94	45,333
C	Aug-87	56,044	0.87	48,805	0.92	45,126
C	Sep-87	47,060	0.87	40,848	0.81	33,081
C	Oct-87	38,037	0.88	33,484	0.86	28,701
C	Nov-87	45,241	0.99	44,864	0.95	42,442
C	Dec-87	38,168	1.00	37,982	0.93	35,504
C	Jan-88	49,180	0.99	48,885	0.84	41,056
C	Feb-88	48,115	0.98	46,951	0.92	43,191
C	Mar-88	58,512	0.97	56,822	0.84	47,515
C	Apr-88	53,139	0.94	50,089	0.83	41,730
C	May-88	48,912	0.93	45,614	0.95	43,450
C	Jun-88	45,943	0.93	42,811	0.75	32,104
C	Jul-88	42,220	0.92	38,977	0.87	33,803
C	Aug-88	47,161	0.91	43,046	0.90	38,542
C	Sep-88	35,746	0.88	31,547	0.83	26,112

Year Type	Month	Patterson (1)	SJRIO-2 Crows/ Pat (2)	Crows Flow 1 x 2 (3)	Pat Low 4-day Avg/ Monthly (4)	Crows 4-Day 3 x 4 (5)
C	Oct-88	28,889	0.93	26,901	0.86	23,260
C	Nov-88	28,893	0.96	27,630	0.88	24,340
C	Dec-88	33,011	0.97	32,182	0.80	25,865
C	Jan-89	35,925	1.00	35,784	0.92	32,813
C	Feb-89	33,951	0.99	33,718	0.87	29,371
C	Mar-89	41,052	0.99	40,828	0.70	28,451
C	Apr-89	47,978	0.95	45,800	0.62	28,426
C	May-89	45,529	0.94	42,613	0.75	31,999
C	Jun-89	35,544	0.93	33,007	0.82	27,145
C	Jul-89	35,353	0.91	32,345	0.82	26,528
C	Aug-89	40,701	0.89	36,301	0.91	32,891
C	Sep-89	32,471	0.87	28,211	0.84	23,742
C	Oct-89	32,910	0.94	30,994	0.74	22,873
C	Nov-89	37,210	1.00	37,126	0.91	33,883
C	Dec-89	38,320	1.00	38,209	0.91	34,825
C	Jan-90	34,170	1.00	34,059	0.88	29,984
C	Feb-90	38,950	0.99	38,557	0.85	32,959
C	Mar-90	37,650	0.99	37,311	0.83	31,152
C	Apr-90	36,300	0.90	32,768	0.78	25,646
C	May-90	32,970	0.91	30,004	0.82	24,563
C	Jun-90	27,050	0.89	23,999	0.72	17,249
C	Jul-90	32,520	0.90	29,114	0.75	21,775
C	Aug-90	32,330	0.90	28,939	0.83	23,942
C	Sep-90	23,880	0.86	20,630	0.82	16,839
C	Oct-90	20,000	0.90	18,088	0.83	15,059
C	Nov-90	20,790	0.96	19,945	0.90	17,939
C	Dec-90	20,620	0.95	19,638	0.94	18,376
C	Jan-91	16,800	0.95	16,038	0.64	10,315
C	Feb-91	16,230	0.88	14,360	0.70	9,987
C	Mar-91	62,660	0.99	61,792	0.52	32,002
C	Apr-91	35,250	0.91	32,026	0.59	18,760
C	May-91	24,790	0.87	21,675	0.86	18,534
C	Jun-91	16,680	0.83	13,921	0.81	11,227
C	Jul-91	19,530	0.86	16,744	0.83	13,902
C	Aug-91	21,280	0.84	17,847	0.87	15,522
C	Sep-91	16,690	0.81	13,565	0.79	10,773

Notes on Flow Records

1. Column 1 contains the monthly flow for the Department of Water Resources gaging station at the Patterson (Pat) Bridge on the San Joaquin River.
2. Column 2 contains the ratio of the monthly flow at Crows Landing (Crows) on the San Joaquin River the Patterson station on the San Joaquin River as calculated by SJRIO-2 in the calibrated mode.
   (a) WY 1973 Crows Landing to Patterson flow ratios were assumed to be similar to WY 79; WYs 1974 & 75 were assumed to be similar to WY 1986; WY 1976 was assumed to be similar to WY 1987.
3. Column 3 calculates the Crows Landing flow based on the ratio in column 2 and the actual Patterson flow in column 1.
   (a) Actual Crows Landing flow data from Department of Water Resources was used for Water Years 1970-72.
4. Column 4 is the ratio of the low 4-day average flow at Patterson to the monthly mean flow at Patterson.
5. Column 5 represents the low 4-day average flow at Crows Landing expressed as a monthly flow value.

TABLE 7

Classification of Water Years (1970-1991)
Based on the San Joaquin River Index

Year Type	Water Years Under Classification	Threshold Millions of Acre-ft
Critical	1976, 1977, 1987-91	C < 2.1
Dry	1972, 1981, 1985	2.1 <= D < 2.5
Below Normal	1971	2.5 <= BN <3.1
Above Normal	1970, 1973, 1979, 1984	3.1 <= AN < 3.8
Wet	1974-75, 1978, 1980, 1982, 1983, 1986	3.8 <= W

TABLE 8

Number of Data Points in Each Flow Regime

Monthly Groups	Water Year Groups		
	Critical	Dry/Below Normal	Above Normal/Wet
Sept-Nov	21	12	33
Dec-Jan	14	8	22
Feb-May	28	16	44
Jun-Aug	21	12	33

The Water Year extends from October through September.

TABLE 9

Monthly Equivalent of the 4-Day Average Low Flow for the San Joaquin River at Crows Landing
Flow in Acre-Feet

(a)

Critical Years: Sep-Nov		
Year Type	Month	Flow
C	Sep-77	2,764
C	Sep-91	10,773
C	Oct-90	15,059
C	Sep-90	16,839
C	Nov-90	17,939
C	Oct-89	22,873
C	Oct-88	23,260
C	Sep-89	23,742
C	Nov-88	24,340
C	Sep-88	26,112
C	Nov-76	28,070
C	Oct-87	28,701
C	Oct-76	29,922
C	Sep-76	31,057
C	Sep-87	33,081
C	Nov-89	33,883
C	Nov-86	39,702
C	Nov-87	42,442
C	Oct-75	53,968
C	Nov-75	55,272
C	Oct-86	62,015

(b)

Dry/Below Normal Years: Sept-Nov		
Year Type	Month	Flow
D	Sep-72	20,202
D	Nov-71	22,105
BN	Sep-71	22,535
BN	Oct-70	22,757
D	Oct-71	24,747
BN	Nov-70	26,389
D	Sep-81	32,336
D	Nov-84	43,404
D	Sep-85	46,526
D	Nov-80	46,778
D	Oct-80	51,993
D	Oct-84	57,852

(c)

Above Normal/Wet Years: Sep-Nov		
Year Type	Month	Flow
W	Oct-77	3,517
W	Nov-77	5,345
W	Oct-81	25,388
W	Nov-81	25,557
AN	Sep-79	26,979
AN	Sep-70	29,220
AN	Nov-72	32,513
W	Nov-85	36,212
AN	Sep-73	38,719
W	Sep-74	39,638
W	Oct-79	40,037
AN	Oct-72	40,139
W	Nov-79	40,285
W	Oct-85	44,313
W	Nov-73	44,524
W	Oct-74	48,014
AN	Sep-84	51,887
W	Oct-73	52,681
AN	Nov-78	56,124
AN	Oct-69	59,154
W	Sep-75	62,643
W	Sep-86	63,744
W	Nov-74	65,101
W	Sep-78	68,440
W	Sep-80	79,758
W	Sep-82	89,662
AN	Nov-69	90,613
AN	Oct-78	94,496
W	Nov-82	114,585
W	Oct-82	150,123
AN	Nov-83	217,043
W	Sep-83	221,562
AN	Oct-83	293,747

TABLE 9

Monthly Equivalent of the 4-Day Average Low Flow for the San Joaquin River at Crows Landing

Flow in Acre-Feet

(d)

Critical Years: Dec, Jan		
Year Type	Month	Flow
C	Jan-91	10,315
C	Dec-90	18,376
C	Dec-76	24,977
C	Dec-88	25,865
C	Jan-77	29,648
C	Jan-90	29,984
C	Jan-89	32,813
C	Dec-89	34,825
C	Dec-87	35,504
C	Jan-76	37,269
C	Dec-86	37,290
C	Jan-87	39,693
C	Jan-88	41,056
C	Dec-75	45,278

(e)

Dry/Below Normal Years: Dec, Jan		
Year Type	Month	Flow
D	Dec-71	25,822
D	Jan-72	41,537
D	Jan-81	43,170
D	Dec-80	54,000
D	Jan-85	56,908
BN	Jan-71	57,960
BN	Dec-70	59,258
D	Dec-84	84,369

(f)

Above Normal/Wet Years: Dec, Jan		
Year Type	Month	Flow
W	Dec-77	11,817
W	Jan-78	19,260
AN	Jan-73	35,395
W	Dec-81	40,032
W	Jan-86	41,489
AN	Jan-79	41,996
W	Dec-85	42,150
AN	Dec-72	44,023
W	Dec-79	44,619
W	Jan-75	51,198
AN	Dec-78	51,561
W	Dec-74	54,046
W	Jan-80	57,939
W	Dec-73	62,219
W	Jan-82	71,193
AN	Dec-69	76,246
AN	Jan-70	91,788
W	Jan-74	156,181
AN	Dec-83	283,363
AN	Jan-84	370,151
W	Jan-83	412,800
W	Dec-82	459,059

TABLE 9

Monthly Equivalent of the 4-Day Average Low Flow for the San Joaquin River at Crows Landing

Flow in Acre-Feet

(g)

Critical Years: Feb-May		
Year Type	Month	Flow
C	Apr-77	5,066
C	May-77	9,272
C	Feb-91	9,987
C	Mar-77	12,223
C	Feb-77	17,772
C	May-91	18,534
C	Apr-91	18,760
C	May-76	24,430
C	May-90	24,563
C	Apr-90	25,646
C	Apr-89	28,426
C	Mar-89	28,451
C	Feb-89	29,371
C	Mar-90	31,152
C	Apr-76	31,955
C	May-89	31,999
C	Mar-91	32,002
C	Feb-90	32,959
C	Mar-76	36,091
C	Feb-76	37,724
C	Apr-88	41,730
C	Feb-87	42,501
C	Feb-88	43,191
C	May-88	43,450
C	May-87	44,552
C	Apr-87	44,601
C	Mar-87	46,572
C	Mar-88	47,515

(h)

Dry/Below Normal Years: Feb-May		
Year Type	Month	Flow
D	May-72	18,555
D	Apr-72	22,060
D	Mar-72	28,343
D	Feb-72	31,537
BN	Apr-71	33,934
BN	May-71	34,298
BN	Feb-71	41,753
BN	Mar-71	42,346
D	Apr-81	42,716
D	Feb-85	45,384
D	Mar-85	47,132
D	Feb-81	47,748
D	May-81	51,453
D	May-85	57,181
D	Mar-81	58,698
D	Apr-85	63,328

(i)

Above Normal/Wet Years: Feb-May		
Year Type	Month	Flow
AN	May-70	30,869
W	Feb-78	38,137
AN	Apr-70	44,029
AN	May-73	47,521
W	Feb-86	50,692
AN	Mar-70	53,155
W	Feb-82	54,538
W	Feb-74	56,174
AN	May-79	58,828
AN	Apr-73	59,392
AN	Apr-79	60,235
W	May-75	60,879
AN	May-84	61,824
W	May-74	64,770
W	Mar-74	70,691
AN	Feb-79	70,727
AN	Apr-84	74,429
W	Apr-74	74,905
W	Mar-75	75,725
W	Feb-75	78,489
AN	Feb-73	79,736
W	Apr-75	84,370
AN	Mar-84	85,326
AN	Feb-70	116,632
AN	Mar-73	126,201
AN	Feb-84	127,364
W	Mar-78	136,246
W	Feb-80	139,733
AN	Mar-79	142,307
W	May-86	156,245
W	May-80	168,170
W	Mar-82	174,907
W	Apr-80	197,637
W	May-82	320,222
W	May-78	346,059
W	Apr-82	372,573
W	Mar-86	379,568
W	Apr-86	407,424
W	Mar-80	470,023
W	Apr-78	584,735
W	May-83	693,362
W	Feb-83	910,630
W	Apr-83	1,031,731
W	Mar-83	1,487,619

TABLE 9

Monthly Equivalent of the 4-Day Average Low Flow for the San Joaquin River at Crows Landing
Flow in Acre-Feet

(j)

Critical Years: Jun-Aug		
Year Type	Month	Flow
C	Jun-77	3,338
C	Jul-77	5,611
C	Aug-77	6,314
C	Jun-91	11,227
C	Jul-91	13,902
C	Aug-91	15,522
C	Jun-90	17,249
C	Jul-90	21,775
C	Aug-90	23,942
C	Jul-76	24,186
C	Jul-89	26,528
C	Jun-76	27,072
C	Jun-89	27,145
C	Aug-76	30,167
C	Jun-88	32,104
C	Aug-89	32,891
C	Jul-88	33,803
C	Aug-88	38,542
C	Jun-87	44,562
C	Aug-87	45,126
C	Jul-87	45,333

(k)

Dry/Below Normal Years: Jun-Aug		
Year Type	Month	Flow
D	Jul-72	13,175
D	Jun-72	14,085
D	Aug-72	16,112
BN	Aug-71	18,449
BN	Jul-71	20,014
BN	Jun-71	25,947
D	Jun-81	28,633
D	Jul-81	35,354
D	Jun-85	35,554
D	Aug-81	38,282
D	Aug-85	44,973
D	Jul-85	46,196

(l)

Above Normal/Wet Years: Jun-Aug		
Year Type	Month	Flow
AN	Jul-70	18,877
AN	Aug-70	21,748
AN	Jun-70	24,285
AN	Aug-79	27,117
AN	Jul-73	28,809
AN	Aug-73	31,973
AN	Jun-73	33,878
W	Aug-80	36,486
W	Aug-74	36,810
W	Jul-74	36,943
W	Jul-75	42,046
W	Jul-78	42,190
W	Aug-78	42,944
W	Aug-75	43,223
AN	Jun-79	43,438
AN	Jul-79	44,442
W	Jun-74	46,917
AN	Jul-84	50,820
W	Jul-80	51,542
AN	Aug-84	51,610
AN	Jun-84	57,016
W	Jul-86	63,750
W	Jun-80	68,165
W	Aug-86	71,873
W	Jun-75	73,718
W	Aug-82	75,446
W	Jun-86	86,801
W	Jul-82	89,860
W	Jun-78	106,125
W	Jun-82	120,860
W	Aug-83	151,173
W	Jul-83	224,311
W	Jun-83	896,063

TABLE 10

Monthly Flow for the San Joaquin River at Crows Landing

Flow in Acre-Feet

(a)

Critical Years: Sep-Nov		
Year Type	Month	Flow
C	Sep-77	3,659
C	Sep-91	13,565
C	Oct-90	18,088
C	Nov-90	19,945
C	Sep-90	20,630
C	Oct-88	26,901
C	Nov-88	27,630
C	Sep-89	28,211
C	Oct-89	30,994
C	Sep-88	31,547
C	Nov-76	33,210
C	Oct-87	33,484
C	Nov-89	37,126
C	Sep-76	38,131
C	Oct-76	38,525
C	Sep-87	40,848
C	Nov-86	44,314
C	Nov-87	44,864
C	Nov-75	58,000
C	Oct-86	74,891
C	Oct-75	98,626

(b)

Dry/Below Normal Years: Sept-Nov		
Year Type	Month	Flow
BN	Sep-71	23,660
D	Nov-71	27,480
BN	Oct-70	28,400
D	Oct-71	31,380
D	Sep-81	33,989
BN	Nov-70	35,570
D	Sep-85	51,351
D	Nov-84	56,970
D	Nov-80	60,653
D	Sep-72	69,230
D	Oct-84	70,832
D	Oct-80	85,708

(c)

Above Normal/Wet Years: Sep-Nov		
Year Type	Month	Flow
W	Oct-77	4,635
W	Nov-77	11,901
AN	Sep-70	31,180
W	Oct-81	34,570
W	Nov-85	39,400
W	Nov-81	40,522
AN	Sep-79	42,296
AN	Sep-73	42,934
W	Sep-74	48,502
W	Oct-85	51,479
W	Nov-79	51,702
AN	Sep-84	55,328
W	Oct-74	55,600
AN	Nov-72	59,988
W	Oct-73	60,045
W	Oct-79	65,335
AN	Oct-72	66,151
W	Nov-73	66,270
W	Nov-74	72,354
W	Sep-86	76,456
W	Sep-75	78,303
AN	Oct-69	89,850
W	Sep-80	91,328
AN	Nov-78	98,511
W	Sep-78	104,013
AN	Nov-69	110,700
W	Sep-82	111,442
AN	Oct-78	114,078
W	Oct-82	166,939
W	Nov-82	198,356
W	Sep-83	253,573
AN	Nov-83	275,556
AN	Oct-83	374,509

TABLE 10

Monthly Flow for the San Joaquin River at Crows Landing

Flow in Acre-Feet

(d)

Critical Years: Dec, Jan		
Year Type	Month	Flow
C	Jan-91	16,038
C	Dec-90	19,638
C	Dec-76	25,963
C	Dec-88	32,182
C	Jan-90	34,059
C	Jan-77	34,668
C	Jan-89	35,784
C	Dec-87	37,982
C	Dec-89	38,209
C	Dec-86	39,445
C	Jan-76	41,365
C	Jan-87	45,943
C	Jan-88	48,885
C	Dec-75	50,191

(e)

Dry/Below Normal Years: Dec, Jan		
Year Type	Month	Flow
D	Dec-71	32,510
D	Dec-80	58,629
D	Jan-81	61,502
D	Jan-85	71,097
BN	Jan-71	72,530
D	Jan-72	72,850
BN	Dec-70	87,560
D	Dec-84	97,084

(f)

Above Normal/Wet Years: Dec, Jan		
Year Type	Month	Flow
W	Dec-77	15,404
W	Jan-86	45,639
W	Dec-81	46,298
W	Dec-79	51,018
AN	Dec-72	51,645
W	Dec-85	54,993
AN	Dec-78	59,622
W	Jan-75	60,723
W	Dec-74	68,833
W	Dec-73	80,646
W	Jan-78	82,783
AN	Jan-73	93,021
W	Jan-82	101,319
AN	Dec-69	105,900
AN	Jan-79	112,429
AN	Jan-70	174,500
W	Jan-74	187,140
W	Jan-80	346,579
AN	Dec-83	472,304
W	Dec-82	684,863
AN	Jan-84	733,459
W	Jan-83	780,387

TABLE 10

Monthly Flow for the San Joaquin River at Crows Landing
Flow in Acre-Feet

(g)

Critical Years: Feb-May		
Year Type	Month	Flow
C	Apr-77	13,089
C	Feb-91	14,360
C	May-77	16,191
C	May-91	21,675
C	Mar-77	22,089
C	Feb-77	26,305
C	May-90	30,004
C	Apr-91	32,026
C	Apr-90	32,768
C	May-76	32,985
C	Feb-89	33,718
C	Mar-90	37,311
C	Feb-90	38,557
C	Apr-76	38,902
C	Mar-89	40,828
C	May-89	42,613
C	Feb-76	43,668
C	May-88	45,614
C	Mar-76	45,764
C	Apr-89	45,800
C	Feb-88	46,951
C	May-87	48,623
C	Apr-87	49,989
C	Apr-88	50,089
C	Feb-87	51,748
C	Mar-88	56,822
C	Mar-91	61,792
C	Mar-87	78,744

(h)

Dry/Below Normal Years: Feb-May		
Year Type	Month	Flow
D	May-72	21,500
D	Apr-72	27,470
D	Mar-72	35,030
BN	May-71	41,320
BN	Apr-71	44,860
BN	Mar-71	49,910
BN	Feb-71	51,030
D	Feb-85	51,855
D	Apr-81	53,995
D	May-81	54,544
D	Feb-72	61,890
D	May-85	61,901
D	Feb-81	62,269
D	Apr-85	69,937
D	Mar-85	72,880
D	Mar-81	86,936

(i)

Above Normal/Wet Years: Feb-May		
Year Type	Month	Flow
AN	May-70	39,870
AN	Apr-70	47,800
AN	May-73	54,332
AN	May-84	69,608
AN	May-79	71,456
W	May-75	77,587
W	May-74	79,723
AN	Apr-84	84,307
AN	Apr-79	89,010
W	Feb-74	91,991
AN	Apr-73	99,357
AN	Mar-84	101,177
W	Mar-74	101,327
W	Apr-74	111,223
W	Apr-75	124,355
W	Mar-75	135,703
W	Feb-82	145,382
AN	Mar-70	148,500
W	Feb-75	150,624
AN	Feb-79	157,542
AN	Feb-84	164,787
AN	Feb-70	168,600
AN	Mar-73	211,277
W	Apr-80	223,650
AN	Mar-79	225,462
W	Mar-82	236,753
W	May-86	240,407
W	May-80	243,114
AN	Feb-73	261,337
W	Feb-86	276,539
W	Feb-78	291,150
W	Mar-78	534,401
W	Feb-80	569,104
W	May-78	631,815
W	May-82	667,086
W	Apr-86	679,444
W	Apr-82	850,055
W	Apr-78	864,347
W	May-83	871,407
W	Mar-86	875,413
W	Mar-80	907,522
W	Apr-83	1,141,624
W	Feb-83	1,261,437
W	Mar-83	1,567,136

TABLE 10

Monthly Flow for the San Joaquin River at Crows Landing

Flow in Acre-Feet

(j)

Critical Years: Jun-Aug		
Year Type	Month	Flow
C	Jun-77	4,988
C	Jul-77	6,433
C	Aug-77	7,756
C	Jun-91	13,921
C	Jul-91	16,744
C	Aug-91	17,847
C	Jun-90	23,999
C	Jul-76	27,338
C	Aug-90	28,939
C	Jul-90	29,114
C	Jun-76	30,216
C	Jul-89	32,345
C	Jun-89	33,007
C	Aug-89	36,301
C	Aug-76	37,576
C	Jul-88	38,977
C	Jun-88	42,811
C	Aug-88	43,046
C	Jul-87	48,211
C	Jun-87	48,634
C	Aug-87	48,805

(k)

Dry/Below Normal Years: Jun-Aug		
Year Type	Month	Flow
D	Jul-72	16,000
D	Jun-72	16,500
D	Aug-72	19,510
BN	Aug-71	20,320
BN	Jul-71	22,820
BN	Jun-71	32,470
D	Jul-81	37,871
D	Jun-81	38,019
D	Aug-81	40,496
D	Aug-85	50,230
D	Jul-85	50,537
D	Jun-85	51,904

(l)

Above Normal/Wet Years: Jun-Aug		
Year Type	Month	Flow
AN	Jul-70	23,000
AN	Aug-70	26,310
AN	Jun-70	27,090
AN	Jul-73	32,485
AN	Aug-73	35,336
AN	Jun-73	36,872
AN	Aug-79	38,730
W	Aug-74	41,297
W	Jul-74	43,359
AN	Jul-79	49,062
W	Aug-78	49,307
W	Jul-75	50,386
W	Jul-78	51,868
W	Aug-80	52,282
W	Aug-75	53,756
AN	Jul-84	56,834
AN	Aug-84	59,103
AN	Jun-79	62,836
AN	Jun-84	67,040
W	Jul-86	75,768
W	Aug-86	75,855
W	Jun-74	79,138
W	Aug-82	80,085
W	Jul-80	88,499
W	Jun-80	95,318
W	Jun-75	122,392
W	Jul-82	129,262
W	Jun-86	139,560
W	Aug-83	178,307
W	Jun-82	181,970
W	Jun-78	203,658
W	Jul-83	760,567
W	Jun-83	942,372

TABLE 11

Percentile Rank within Each Flow Regime which Produces the Desired Frequency of Violation

Monthly Mean Water Quality Objective

(a)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	4th	7.5th	10th	15th	25th
D/BN	Sep-Nov	0th	0th	5th	5th	20th
AN/W	Sep-Nov	**	**	5th	5th	15th
C	Dec-Jan	4th	7.5th	10th	15th	25th
D/BN	Dec-Jan	0th	0th	5th	5th	20th
AN/W	Dec-Jan	**	**	5th	5th	15th
C	Feb-May	4th	7.5th	10th	15th	25th
D/BN	Feb-May	0th	0th	5th	5th	20th
AN/W	Feb-May	0th	0th	5th	5th	15th
C	Jun-Aug	4th	7.5th	10th	15th	25th
D/BN	Jun-Aug	0th	0th	5th	5th	20th
AN/W	Jun-Aug	0th	0th	5th	5th	15th

4-Day Average Water Quality Objective

(b)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	3.5th	7.5th	10th	15th	25th
D/BN	Sep-Nov	0th	0th	5th	5th	20th
AN/W	Sep-Nov	**	**	5th	5th	15th
C	Dec-Jan	3.5th	7.5th	10th	15th	25th
D/BN	Dec-Jan	0th	0th	5th	5th	20th
AN/W	Dec-Jan	**	**	**	**	15th
C	Feb-May	3.5th	7.5th	10th	15th	25th
D/BN	Feb-May	0th	0th	5th	5th	20th
AN/W	Feb-May	0th	0th	5th	5th	15th
C	Jun-Aug	3.5th	7.5th	10th	15th	25th
D/BN	Jun-Aug	0th	0th	5th	5th	20th
AN/W	Jun-Aug	0th	0th	5th	5th	15th

** If the Design Flow of the Dry/Below Normal or Above Normal/ Wet flow regime was less than the corrresponding Design Flow for the Critical year, the D/BN or AN/W Design Flow was set equal to the critical year Design Flow.

TABLE 12

Design Flow (acre-feet/month) within Each Flow Regime which Produces the Desired Frequency of Violation

Monthly Mean Water Quality Objective

(a)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	11,583	15,826	18,088	19,945	26,901
D/BN	Sep-Nov	23,660	23,660	25,761	25,761	28,996
AN/W	Sep-Nov	11,583	15,826	23,468	23,468	40,297
C	Dec-Jan	17,910	19,548	21,535	25,647	32,651
D/BN	Dec-Jan	32,510	32,510	41,652	41,652	59,778
AN/W	Dec-Jan	17,910	19,548	45,672	45,672	51,112
C	Feb-May	14,507	16,328	20,030	22,300	31,520
D/BN	Feb-May	21,500	21,500	25,978	25,978	41,320
AN/W	Feb-May	39,870	39,870	56,624	56,624	81,786
C	Jun-Aug	6,144	7,095	7,756	13,921	17,847
D/BN	Jun-Aug	16,000	16,000	16,275	16,275	19,672
AN/W	Jun-Aug	23,000	23,000	26,778	26,778	36,565

4-Day Average Water Quality Objective

(b)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	8,371	12,916	15,059	16,839	22,873
D/BN	Sep-Nov	20,202	20,202	21,249	21,249	22,579
AN/W	Sep-Nov	8,371	12,916	17,371	17,371	28,772
C	Dec-Jan	13,983	18,174	20,356	24,647	26,811
D/BN	Dec-Jan	25,822	25,822	31,322	31,322	42,190
AN/W	Dec-Jan	13,983	18,174	20,356	24,647	40,251
C	Feb-May	9,041	10,043	11,552	17,810	23,013
D/BN	Feb-May	18,555	18,555	21,184	21,184	31,537
AN/W	Feb-May	30,869	30,869	44,553	44,553	55,274
C	Jun-Aug	4,929	5,963	6,314	11,227	15,522
D/BN	Jun-Aug	13,175	13,175	13,676	13,676	16,579
AN/W	Jun-Aug	18,877	18,877	23,270	23,270	31,340

** If the Design Flow of the Dry/Below Normal or Above Normal/ Wet flow regime was less than the corrresponding Design Flow for the Critical year, the D/BN or AN/W Design Flow was set equal to the critical year Design Flow.

TABLE 13

The Total Maximum Monthly Load (lbs/month) within Each Flow Regime which Produces the Desired Frequency of Violation of a 5 μg/L Objective

Monthly Mean Water Quality Objective

(a)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	157	215	246	271	365
D/BN	Sep-Nov	321	321	350	350	394
AN/W	Sep-Nov	157	215	319	319	547
C	Dec-Jan	243	266	293	348	444
D/BN	Dec-Jan	442	442	566	566	812
AN/W	Dec-Jan	243	266	620	620	694
C	Feb-May	197	222	272	303	428
D/BN	Feb-May	292	292	353	353	561
AN/W	Feb-May	542	542	769	769	1,111
C	Jun-Aug	83	96	105	189	242
D/BN	Jun-Aug	217	217	221	221	267
AN/W	Jun-Aug	312	312	364	364	497

4-Day Average Water Quality Objective

(b)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	114	175	205	229	311
D/BN	Sep-Nov	274	274	289	289	307
AN/W	Sep-Nov	114	175	236	236	391
C	Dec-Jan	190	247	277	335	364
D/BN	Dec-Jan	351	351	425	425	573
AN/W	Dec-Jan	190	247	277	335	547
C	Feb-May	123	136	157	242	313
D/BN	Feb-May	252	252	288	288	428
AN/W	Feb-May	419	419	605	605	751
C	Jun-Aug	67	81	86	152	211
D/BN	Jun-Aug	179	179	186	186	225
AN/W	Jun-Aug	256	256	316	316	426

TABLE 14

Calculated Concentration in the San Joaquin River at Crows Landing (Water Years 1970-1991) Based on a Once a Year Excursion Rate and 5 μg/L Monthly Mean Water Quality Objective

Year Type	Month	Flow Acre-Feet (1)	TMML Pounds (2)	Conc. μg/l (3)
AN	Oct-69	89,850	319	1.3
AN	Nov-69	110,700	319	1.1
AN	Dec-69	105,900	620	2.2
AN	Jan-70	174,500	620	1.3
AN	Feb-70	168,600	769	1.7
AN	Mar-70	148,500	769	1.9
AN	Apr-70	47,800	769	5.9
AN	May-70	39,870	769	7.1
AN	Jun-70	27,090	364	4.9
AN	Jul-70	23,000	364	5.8
AN	Aug-70	26,310	364	5.1
AN	Sep-70	31,180	319	3.8
BN	Oct-70	28,400	350	4.5
BN	Nov-70	35,570	350	3.6
BN	Dec-70	87,560	566	2.4
BN	Jan-71	72,530	566	2.9
BN	Feb-71	51,030	353	2.5
BN	Mar-71	49,910	353	2.6
BN	Apr-71	44,860	353	2.9
BN	May-71	41,320	353	3.1
BN	Jun-71	32,470	221	2.5
BN	Jul-71	22,820	221	3.6
BN	Aug-71	20,320	221	4.0
BN	Sep-71	23,660	350	5.4
D	Oct-71	31,380	350	4.1
D	Nov-71	27,480	350	4.7
D	Dec-71	32,510	566	6.4
D	Jan-72	72,850	566	2.9
D	Feb-72	61,890	353	2.1
D	Mar-72	35,030	353	3.7
D	Apr-72	27,470	353	4.7
D	May-72	21,500	353	6.0
D	Jun-72	16,500	221	4.9
D	Jul-72	16,000	221	5.1
D	Aug-72	19,510	221	4.2
D	Sep-72	69,230	350	1.9
AN	Oct-72	66,151	319	1.8
AN	Nov-72	59,988	319	2.0
AN	Dec-72	51,645	620	4.4
AN	Jan-73	93,021	620	2.5
AN	Feb-73	261,337	769	1.1
AN	Mar-73	211,277	769	1.3
AN	Apr-73	99,357	769	2.8
AN	May-73	54,332	769	5.2
AN	Jun-73	36,872	364	3.6
AN	Jul-73	32,485	364	4.1
AN	Aug-73	35,336	364	3.8
AN	Sep-73	42,934	319	2.7

Year Type	Month	Flow Acre-Feet (1)	TMML Pounds (2)	Conc. μg/l (3)
W	Oct-73	60,045	319	2.0
W	Nov-73	66,270	319	1.8
W	Dec-73	80,646	620	2.8
W	Jan-74	187,140	620	1.2
W	Feb-74	91,991	769	3.1
W	Mar-74	101,327	769	2.8
W	Apr-74	111,223	769	2.5
W	May-74	79,723	769	3.6
W	Jun-74	79,138	364	1.7
W	Jul-74	43,359	364	3.1
W	Aug-74	41,297	364	3.2
W	Sep-74	48,502	319	2.4
W	Oct-74	55,600	319	2.1
W	Nov-74	72,354	319	1.6
W	Dec-74	68,833	620	3.3
W	Jan-75	60,723	620	3.8
W	Feb-75	150,624	769	1.9
W	Mar-75	135,703	769	2.1
W	Apr-75	124,355	769	2.3
W	May-75	77,587	769	3.6
W	Jun-75	122,392	364	1.1
W	Jul-75	50,386	364	2.7
W	Aug-75	53,756	364	2.5
W	Sep-75	78,303	319	1.5
C	Oct-75	98,626	246	0.9
C	Nov-75	58,000	246	1.6
C	Dec-75	50,191	293	2.1
C	Jan-76	41,365	293	2.6
C	Feb-76	43,668	272	2.3
C	Mar-76	45,764	272	2.2
C	Apr-76	38,902	272	2.6
C	May-76	32,985	272	3.0
C	Jun-76	30,216	105	1.3
C	Jul-76	27,338	105	1.4
C	Aug-76	37,576	105	1.0
C	Sep-76	38,131	246	2.4
C	Oct-76	38,525	246	2.3
C	Nov-76	33,210	246	2.7
C	Dec-76	25,963	293	4.1
C	Jan-77	34,668	293	3.1
C	Feb-77	26,305	272	3.8
C	Mar-77	22,089	272	4.5
C	Apr-77	13,089	272	7.7
C	May-77	16,191	272	6.2
C	Jun-77	4,988	105	7.8
C	Jul-77	6,433	105	6.0
C	Aug-77	7,756	105	5.0
C	Sep-77	3,659	246	24.7

TABLE 14

Calculated Concentration in the San Joaquin River at Crows Landing (Water Years 1970-1991) Based on a Once a Year Excursion Rate and 5 µg/L Monthly Mean Water Quality Objective

Year Type	Month	Flow Acre-Feet (1)	TMML Pounds (2)	Conc. µg/l (3)
W	Oct-77	4,635	319	25.3
W	Nov-77	11,901	319	9.9
W	Dec-77	15,404	620	14.8
W	Jan-78	82,783	620	2.8
W	Feb-78	291,150	769	1.0
W	Mar-78	534,401	769	0.5
W	Apr-78	864,347	769	0.3
W	May-78	631,815	769	0.4
W	Jun-78	203,658	364	0.7
W	Jul-78	51,868	364	2.6
W	Aug-78	49,307	364	2.7
W	Sep-78	104,013	319	1.1
AN	Oct-78	114,078	319	1.0
AN	Nov-78	98,511	319	1.2
AN	Dec-78	59,622	620	3.8
AN	Jan-79	112,429	620	2.0
AN	Feb-79	157,542	769	1.8
AN	Mar-79	225,462	769	1.3
AN	Apr-79	89,010	769	3.2
AN	May-79	71,456	769	4.0
AN	Jun-79	62,836	364	2.1
AN	Jul-79	49,062	364	2.7
AN	Aug-79	38,730	364	3.5
AN	Sep-79	42,296	319	2.8
W	Oct-79	65,335	319	1.8
W	Nov-79	51,702	319	2.3
W	Dec-79	51,018	620	4.5
W	Jan-80	346,579	620	0.7
W	Feb-80	569,104	769	0.5
W	Mar-80	907,522	769	0.3
W	Apr-80	223,650	769	1.3
W	May-80	243,114	769	1.2
W	Jun-80	95,318	364	1.4
W	Jul-80	88,499	364	1.5
W	Aug-80	52,282	364	2.6
W	Sep-80	91,328	319	1.3
D	Oct-80	85,708	350	1.5
D	Nov-80	60,653	350	2.1
D	Dec-80	58,629	566	3.6
D	Jan-81	61,502	566	3.4
D	Feb-81	62,269	353	2.1
D	Mar-81	86,936	353	1.5
D	Apr-81	53,995	353	2.4
D	May-81	54,544	353	2.4
D	Jun-81	38,019	221	2.1
D	Jul-81	37,871	221	2.1
D	Aug-81	40,496	221	2.0
D	Sep-81	33,989	350	3.8

Year Type	Month	Flow Acre-Feet (1)	TMML Pounds (2)	Conc. µg/l (3)
W	Oct-81	34,570	319	3.4
W	Nov-81	40,522	319	2.9
W	Dec-81	46,298	620	4.9
W	Jan-82	101,319	620	2.3
W	Feb-82	145,382	769	1.9
W	Mar-82	236,753	769	1.2
W	Apr-82	850,055	769	0.3
W	May-82	667,086	769	0.4
W	Jun-82	181,970	364	0.7
W	Jul-82	129,262	364	1.0
W	Aug-82	80,085	364	1.7
W	Sep-82	111,442	319	1.1
W	Oct-82	166,939	319	0.7
W	Nov-82	198,356	319	0.6
W	Dec-82	684,863	620	0.3
W	Jan-83	780,387	620	0.3
W	Feb-83	1,261,437	769	0.2
W	Mar-83	1,567,136	769	0.2
W	Apr-83	1,141,624	769	0.2
W	May-83	871,407	769	0.3
W	Jun-83	942,372	364	0.1
W	Jul-83	760,567	364	0.2
W	Aug-83	178,307	364	0.8
W	Sep-83	253,573	319	0.5
AN	Oct-83	374,509	319	0.3
AN	Nov-83	275,556	319	0.4
AN	Dec-83	472,304	620	0.5
AN	Jan-84	733,459	620	0.3
AN	Feb-84	164,787	769	1.7
AN	Mar-84	101,177	769	2.8
AN	Apr-84	84,307	769	3.4
AN	May-84	69,608	769	4.1
AN	Jun-84	67,040	364	2.0
AN	Jul-84	56,834	364	2.4
AN	Aug-84	59,103	364	2.3
AN	Sep-84	55,328	319	2.1
D	Oct-84	70,832	350	1.8
D	Nov-84	56,970	350	2.3
D	Dec-84	97,084	566	2.1
D	Jan-85	71,097	566	2.9
D	Feb-85	51,855	353	2.5
D	Mar-85	72,880	353	1.8
D	Apr-85	69,937	353	1.9
D	May-85	61,901	353	2.1
D	Jun-85	51,904	221	1.6
D	Jul-85	50,537	221	1.6
D	Aug-85	50,230	221	1.6
D	Sep-85	51,351	350	2.5

TABLE 14

Calculated Concentration in the San Joaquin River at Crows Landing (Water Years 1970-1991) Based on a Once a Year Excursion Rate and 5 µg/L Monthly Mean Water Quality Objective

Year Type	Month	Flow Acre-Feet (1)	TMML Pounds (2)	Conc. µg/l (3)
W	Oct-85	51,479	319	2.3
W	Nov-85	39,400	319	3.0
W	Dec-85	54,993	620	4.2
W	Jan-86	45,639	620	5.0
W	Feb-86	276,539	769	1.0
W	Mar-86	875,413	769	0.3
W	Apr-86	679,444	769	0.4
W	May-86	240,407	769	1.2
W	Jun-86	139,560	364	1.0
W	Jul-86	75,768	364	1.8
W	Aug-86	75,855	364	1.8
W	Sep-86	76,456	319	1.5
C	Oct-86	74,891	246	1.2
C	Nov-86	44,314	246	2.0
C	Dec-86	39,445	293	2.7
C	Jan-87	45,943	293	2.3
C	Feb-87	51,748	272	1.9
C	Mar-87	78,744	272	1.3
C	Apr-87	49,989	272	2.0
C	May-87	48,623	272	2.1
C	Jun-87	48,634	105	0.8
C	Jul-87	48,211	105	0.8
C	Aug-87	48,805	105	0.8
C	Sep-87	40,848	246	2.2
C	Oct-87	33,484	246	2.7
C	Nov-87	44,864	246	2.0
C	Dec-87	37,982	293	2.8
C	Jan-88	48,885	293	2.2
C	Feb-88	46,951	272	2.1
C	Mar-88	56,822	272	1.8
C	Apr-88	50,089	272	2.0
C	May-88	45,614	272	2.2
C	Jun-88	42,811	105	0.9
C	Jul-88	38,977	105	1.0
C	Aug-88	43,046	105	0.9
C	Sep-88	31,547	246	2.9
C	Oct-88	26,901	246	3.4
C	Nov-88	27,630	246	3.3
C	Dec-88	32,182	293	3.3
C	Jan-89	35,784	293	3.0
C	Feb-89	33,718	272	3.0
C	Mar-89	40,828	272	2.5
C	Apr-89	45,800	272	2.2
C	May-89	42,613	272	2.4
C	Jun-89	33,007	105	1.2
C	Jul-89	32,345	105	1.2
C	Aug-89	36,301	105	1.1
C	Sep-89	28,211	246	3.2
C	Oct-89	30,994	246	2.9
C	Nov-89	37,126	246	2.4
C	Dec-89	38,209	293	2.8
C	Jan-90	34,059	293	3.2
C	Feb-90	38,557	272	2.6
C	Mar-90	37,311	272	2.7
C	Apr-90	32,768	272	3.1
C	May-90	30,004	272	3.3
C	Jun-90	23,999	105	1.6
C	Jul-90	29,114	105	1.3
C	Aug-90	28,939	105	1.3
C	Sep-90	20,630	246	4.4
C	Oct-90	18,088	246	5.0
C	Nov-90	19,945	246	4.5
C	Dec-90	19,638	293	5.5
C	Jan-91	16,038	293	6.7
C	Feb-91	14,360	272	7.0
C	Mar-91	61,792	272	1.6
C	Apr-91	32,026	272	3.1
C	May-91	21,675	272	4.6
C	Jun-91	13,921	105	2.8
C	Jul-91	16,744	105	2.3
C	Aug-91	17,847	105	2.2
C	Sep-91	13,565	246	6.7

Notes - Flow from Table 6, column 3; TMML from Table 13. The model calculated value for January 1986 is slightly greater than 5 µg/L. All other model results which indicate a value of 5.0 µg/L are either equal to or less than 5 µg/L.

TABLE 15

Comparison of Mud Slough (north) and Salt Slough Selenium Loads to Selenium Loads in the San Joaquin River at Crows Landing

(a)

Month	SS & MS Se Load Pounds 1	Crows Flow Acre-Ft 2	Crows Se Conc. µg/L 3	Crows Load 2x3 Pounds 4	MS+SS Load/ Crows Load (1/4) 5
Oct-87	221	33,484	1.9	168	131%
Nov-87	209	44,864	2.8	341	61%
Dec-87	208	37,982	2.9	294	71%
Jan-88	666	48,885	6.7	893	75%
Feb-88	1,033	46,951	12.0	1,531	67%
Mar-88	1,247	56,822	8.5	1,312	95%
Apr-88	815	50,089	7.2	980	83%
May-88	657	45,614	5.6	698	94%
Jun-88	728	42,811	6.9	802	91%
Jul-88	849	38,977	8.3	879	97%
Aug-88	805	43,046	7.9	918	88%
Sep-88	557	31,547	6.9	595	94%
Oct-88	346	26,901	5.5	398	87%
Nov-88	215	27,630	4.2	317	68%
Dec-88	268	32,182	4.5	389	69%
Jan-89	552	35,784	7.2	703	79%
Feb-89	913	33,718	9.7	889	103%
Mar-89	1,102	40,828	10.9	1,207	91%
Apr-89	1,166	45,800	7.6	949	123%
May-89	946	42,613	7.8	901	105%
Jun-89	1,021	33,007	8.9	800	128%
Jul-89	659	32,345	7.5	659	100%
Aug-89	620	36,301	6.3	616	101%
Sep-89	569	28,211	5.5	422	135%

Month	SS & MS Se Load Pounds 1	Crows Flow Acre-Ft 2	Crows Se Conc. µg/L 3	Crows Load 2x3 Pounds 4	MS+SS Load/ Crows Load (1/4) 5
Oct-89	297	30,994	3.7	312	95%
Nov-89	360	37,126	3.6	358	101%
Dec-89	503	38,209	5.8	599	84%
Jan-90	826	34,059	9.0	830	99%
Feb-90	1,206	38,557	12.0	1,257	96%
Mar-90	1,130	37,311	11.0	1,113	102%
Apr-90	646	32,768	7.9	705	92%
May-90	760	30,004	9.9	809	94%
Jun-90	541	23,999	7.3	474	114%
Jul-90	463	29,114	5.9	467	99%
Aug-90	458	28,939	6.2	484	95%
Sep-90	323	20,630	3.3	185	175%
Oct-90	94	18,088	2.8	135	70%
Nov-90	66	19,945	1.2	64	103%
Dec-90	234	19,638	5.5	291	81%
Jan-91	248	16,038	7.4	323	77%
Feb-91	244	14,360	8.5	330	74%
Mar-91	803	61,792	6.2	1,044	77%
Apr-91	676	32,026	8.1	707	96%
May-91	396	21,675	6.3	373	106%
Jun-91	323	13,921	8.4	316	102%
Jul-91	328	16,744	5.5	250	131%
Aug-91	224	17,847	4.9	238	94%
Sep-91	172	13,565	4.2	156	111%

TABLE 15

(b)

Percentage of Mud Slough (north) and Salt Slough (MS +SS) Selenium Load in the San Joaquin River at Crows Landing (Crows)

	MS + SS/ Crows
WY 88	87%
WY 89	99%
WY 90	104%
WY 91	93%
Average	96%
Std Dev.	21%

TABLE 16

Simple Waste Load Allocation Calculation Based on a 1 in 3 Year Exceedance Rate and a 5 µg/L Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	TMML 1x2 lbs 3	Merced River Flow Acre-Ft 4	Merced River Conc. µg/L 5	SJR @ Lander Flow Acre-Ft 6	SJR@ Lander Conc. µg/L 7	Bkgnd Load 4x5+ 6x7 lbs 8	MOS (2) x 10% lbs 9	WLA 2-8-9 lbs 10
Sept-Nov	C	5	11,583	157	4,242	0.2	70	0.5	2	16	139
Sept-Nov	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	8	32	281
Sept-Nov	AN/W	5	11,583	157	4,242	0.2	70	0.5	2	16	139
Dec-Jan	C	5	17,910	243	10,151	0.2	8	0.5	6	24	213
Dec-Jan	D/BN	5	32,510	442	17,140	0.2	2,029	0.5	12	44	385
Dec-Jan	AN/W	5	17,910	243	10,151	0.2	8	0.5	6	24	213
Feb-May	C	5	14,507	197	3,598	0.2	122	0.5	2	20	175
Feb-May	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	7	29	256
Feb-May	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	16	54	472
Jun-Aug	C	5	6,144	83	1,000	0.2	58	0.5	1	8	74
Jun-Aug	D/BN	5	16,000	217	6,220	0.2	412	0.5	4	22	192
Jun-Aug	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	7	31	274

For 1 in 3 yrs, the 4th percentile for critical years and lowest flow for other year types was used.
If lowest flow of other year types was lower than the 4th percentile of critical years,
the 4th percentile of the critical year was used.

Column 2 data is from Table 12(a).

TABLE 17

Waste Load Allocation (pounds/month) within Each Flow Regime which produces the Desired Frequency of Violation

Monthly Mean Water Quality Objective

(a)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	139	192	220	240	327
D/BN	Sep-Nov	281	281	304	304	344
AN/W	Sep-Nov	139	192	278	278	478
C	Dec-Jan	213	233	258	305	392
D/BN	Dec-Jan	385	385	493	493	710
AN/W	Dec-Jan	213	233	540	540	606
C	Feb-May	175	196	241	267	380
D/BN	Feb-May	256	256	309	309	495
AN/W	Feb-May	472	472	677	677	970
C	Jun-Aug	74	84	94	169	217
D/BN	Jun-Aug	192	192	195	195	234
AN/W	Jun-Aug	274	274	319	319	438

4-Day Average Water Quality Objective

(b)

Year Type	Monthly Grouping	Frequency of Violation - Once Every				
		3 Years	2 Years	1 Year	10 Months	5 Months
C	Sep-Nov	100	157	183	205	278
D/BN	Sep-Nov	237	237	249	249	269
AN/W	Sep-Nov	100	157	204	204	341
C	Dec-Jan	168	217	244	294	320
D/BN	Dec-Jan	306	306	373	373	501
AN/W	Dec-Jan	168	217	244	294	477
C	Feb-May	109	121	139	214	278
D/BN	Feb-May	222	221	252	252	377
AN/W	Feb-May	366	365	528	528	635
C	Jun-Aug	60	72	77	137	189
D/BN	Jun-Aug	158	158	164	164	199
AN/W	Jun-Aug	225	225	276	276	374

TABLE 18

The Effect on the Waste Load Allocation (WLA) of
Changing the Water Quality Objective versus
Changing the Exceedance Rate

Objective µg/L	Exceedance Rate	Annual WLA
5	1 in 3 yr	1,769
8	1 in 3 yr	2,847
5	1 in 19 mos.	2,833

TABLE 19

Comparison of Historical Selenium (Se) Loads from Mud Slough (north) and Salt Slough (MS & SS) with Calculated Waste Load Allocations (WLA) based on a One in Five Month Exceedance Rate of a 5 μg/L Monthly Mean Water Quality Objective. Historical Exceedance Rates are found based on the Actual Selenium Concentration (μg/L) in the San Joaquin River at Crows Landing

	MS & SS Se Load (lbs)		Crows Landing
Month	Actual Load	WLA	Actual Se Conc.
Oct-85	144	478	1.0
Dec-85	240	606	2.0
Jan-86	324	606	3.7
Feb-86	1,246	970	3.0
Mar-86	848	970	1.0
Apr-86	1,044	970	0.8
May-86	741	970	0.5
Jun-86	609	438	2.7
Jul-86	562	438	3.1
Aug-86	735	438	3.6
Sep-86	328	478	2.3
Oct-86	179	327	3.0
Nov-86	407	327	3.6
Dec-86	550	392	5.3
Jan-87	530	392	5.8
Feb-87	974	380	12.0
Mar-87	1,520	380	10.3
Apr-87	878	380	8.5
May-87	648	380	5.5
Jun-87	763	217	6.3
Jul-87	706	217	5.6
Aug-87	665	217	5.6
Sep-87	345	327	4.2
Oct-87	221	327	1.9
Nov-87	209	327	2.8
Dec-87	208	392	2.9
Jan-88	666	392	6.7
Feb-88	1,033	380	12.0
Mar-88	1,247	380	8.5
Apr-88	815	380	7.2
May-88	657	380	5.6

TABLE 19

Comparison of Historical Selenium (Se) Loads from Mud Slough (north) and Salt Slough (MS & SS) with Calculated Waste Load Allocations (WLA) based on a One in Five Month Exceedance Rate of a 5 µg/L Monthly Mean Water Quality Objective. Historical Exceedance Rates are found based on the Actual Selenium Concentration (µg/L) in the San Joaquin River at Crows Landing

	MS & SS Se Load (lbs)		Crows Landing
Month	Actual Load	WLA	Actual Se Conc.
Jun-88	728	217	6.9
Jul-88	849	217	8.3
Aug-88	805	217	7.9
Sep-88	557	327	6.9
Oct-88	346	327	5.5
Nov-88	215	327	4.2
Dec-88	268	392	4.5
Jan-89	552	392	7.2
Feb-89	913	380	9.7
Mar-89	1,102	380	10.9
Apr-89	1,166	380	7.6
May-89	946	380	7.8
Jun-89	1,021	217	8.9
Jul-89	659	217	7.5
Aug-89	620	217	6.3
Sep-89	569	327	5.5
Oct-89	297	327	3.7
Nov-89	360	327	3.6
Dec-89	503	392	5.8
Jan-90	826	392	9.0
Feb-90	1,206	380	12.0
Mar-90	1,130	380	11.0
Apr-90	646	380	7.9
May-90	760	380	9.9
Jun-90	541	217	7.3
Jul-90	463	217	5.9
Aug-90	458	217	6.2
Sep-90	323	327	3.3
Oct-90	94	327	2.8
Nov-90	66	327	1.2
Dec-90	234	392	5.5

TABLE 19

Comparison of Historical Selenium (Se) Loads from Mud Slough (north) and Salt Slough (MS & SS) with Calculated Waste Load Allocations (WLA) based on a One in Five Month Exceedance Rate of a 5 µg/L Monthly Mean Water Quality Objective. Historical Exceedance Rates are found based on the Actual Selenium Concentration (µg/L) in the San Joaquin River at Crows Landing

	MS & SS Se Load (lbs)		Crows Landing
Month	Actual Load	WLA	Actual Se Conc.
Jan-91	248	392	7.4
Feb-91	244	380	8.5
Mar-91	803	380	6.2
Apr-91	676	380	8.1
May-91	396	380	6.3
Jun-91	323	217	8.4
Jul-91	328	217	5.5
Aug-91	224	217	4.9
Sep-91	172	327	4.2
Oct-91	13	327	1.0
Nov-91	132	327	2.2
Dec-91	91	392	1.5
Jan-92	311	392	4.0
Feb-92	439	380	4.2
Mar-92	661	380	5.9
Apr-92	540	380	8.2
May-92	208	380	5.5
Jun-92	295	217	6.4
Jul-92	154	217	4.7
Aug-92	92	217	3.5
Sep-92	38	327	1.3

Summary Statistics

	Actual Load > Allowable Load	Actual Load < Allowable Load
Total # of Months	55	28
# of Months > 5 µg/L	45	4
Violation Rate	82%	14%

TABLE 20

Effect of Considering Wetland Load Contributions on the Calculated Waste Load Allocation; 1 in 3 year Exceedance Rate of a Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	TMML 1x2 lbs 3	Merced River Flow Acre-Ft 4	Merced River Conc. µg/L 5	SJR@ Lander Acre-Ft 6	SJR@ Lander Conc. µg/L 7	Wet-land Flow Acre-Ft 8	Wet-land Conc µg/L 9	Bkgnd Load 4x5+6x7 +8x9 lbs 10	MOS (2) x 10% lbs 11	WLA DSA 3-10-11 lbs 12
Sept	C	5	11,583	157	4,242	0.2	70	0.5	1,000	1	5	16	136
Sept	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	1,900	1	13	32	276
Sept	AN/W	5	11,583	157	4,242	0.2	70	0.5	1,900	1	8	16	134
Oct	C	5	11,583	157	4,242	0.2	70	0.5	1,700	1	7	16	135
Oct	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	3,300	1	17	32	272
Oct	AN/W	5	11,583	157	4,242	0.2	70	0.5	3,300	1	11	16	130
Nov	C	5	11,583	157	4,242	0.2	70	0.5	1,700	1	7	16	135
Nov	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	3,300	1	17	32	272
Nov	AN/W	5	11,583	157	4,242	0.2	70	0.5	3,300	1	11	16	130
Dec	C	5	17,910	243	10,151	0.2	8	0.5	1,600	1	10	24	209
Dec	D/BN	5	32,510	442	17,140	0.2	2,029	0.5	3,200	1	21	44	377
Dec	AN/W	5	17,910	243	10,151	0.2	8	0.5	3,200	1	14	24	205
Jan	C	5	17,910	243	10,151	0.2	8	0.5	1,700	1	10	24	209
Jan	D/BN	5	32,510	442	17,140	0.2	2,029	0.5	3,300	1	21	44	376
Jan	AN/W	5	17,910	243	10,151	0.2	8	0.5	3,300	1	14	24	204
Feb	C	5	14,507	197	3,598	0.2	122	0.5	7,200	1	22	20	156
Feb	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	14,400	1	46	29	217
Feb	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	14,400	1	55	54	432
Mar	C	5	14,507	197	3,598	0.2	122	0.5	7,300	1	22	20	155
Mar	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	14,400	1	46	29	217
Mar	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	14,400	1	55	54	432
Apr	C	5	14,507	197	3,598	0.2	122	0.5	4,000	1	13	20	164
Apr	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	7,800	1	28	29	235
Apr	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	7,800	1	37	54	450
May	C	5	14,507	197	3,598	0.2	122	0.5	2,700	1	9	20	168
May	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	5,300	1	21	29	242
May	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	5,300	1	30	54	457
Jun	C	5	6,144	83	1,000	0.2	58	0.5	2,400	1	7	8	68
Jun	D/BN	5	16,000	217	6,220	0.2	412	0.5	4,600	1	16	22	179
Jun	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	4,600	1	20	31	262
Jul	C	5	6,144	83	1,000	0.2	58	0.5	2,000	1	6	8	69
Jul	D/BN	5	16,000	217	6,220	0.2	412	0.5	3,900	1	15	22	181
Jul	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	3,900	1	18	31	264
Aug	C	5	6,144	83	1,000	0.2	58	0.5	0	1	1	8	74
Aug	D/BN	5	16,000	217	6,220	0.2	412	0.5	0	1	4	22	192
Aug	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	0	1	7	31	274

Wetland flow estimates are from D.G. Swain and N.W.T. Quin (April 1991).

TABLE 21

Effect of Considering Wetland Load Contributions and Adjustments in Design Flow Due to Drainage Reduction on the Calculated Waste Load Allocation; 1 in 3 year Exceedance Rate of a Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	TMML 1x2 lbs 3	Merced River Flow Acre-Ft 4	Merced River Conc. µg/L 5	SJR@ Lander Acre-Ft 6	SJR@ Lander Conc. µg/L 7	Wet-land Flow Acre-Ft 8	Wet-land Conc µg/L 9	Bkgnd Load 4x5+6x7 +8x9 lbs 10	MOS (2) x 10% lbs 11	WLA DSA 3-10-11 lbs 12	Est. Drain Flow Acre-Ft 13	Est. Drain Conc. µg/L 14	Est. Drain Load 13x14 lbs 15	Redtn in Drain Flow ** Acre-Ft 16	Adj Design Flow 2-16 Acre-Ft 17	Adj Drain WLA ## lbs 18
Sept	C	5	11,583	157	4,242	0.2	70	0.5	1,000	1	5	16	136	584	211	335	353	11,230	132
Sept	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	1,900	1	13	32	276	584	211	335	105	23,555	275
Sept	AN/W	5	11,583	157	4,242	0.2	70	0.5	1,900	1	8	16	134	584	211	335	358	11,226	130
Oct	C	5	11,583	157	4,242	0.2	70	0.5	1,700	1	7	16	135	1,033	211	592	816	10,767	125
Oct	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	3,300	1	17	32	272	1,033	211	592	571	23,089	265
Oct	AN/W	5	11,583	157	4,242	0.2	70	0.5	3,300	1	11	16	130	1,033	211	592	824	10,760	120
Nov	C	5	11,583	157	4,242	0.2	70	0.5	1,700	1	7	16	135	878	211	503	657	10,926	127
Nov	D/BN	5	23,660	321	9,830	0.2	2,073	0.5	3,300	1	17	32	272	878	211	503	412	23,248	267
Nov	AN/W	5	11,583	157	4,242	0.2	70	0.5	3,300	1	11	16	130	878	211	503	665	10,918	122
Dec	C	5	17,910	243	10,151	0.2	8	0.5	1,600	1	10	24	209	928	211	532	576	17,334	202
Dec	D/BN	5	32,510	442	17,140	0.2	2,029	0.5	3,200	1	21	44	377	928	211	532	277	32,233	373
Dec	AN/W	5	17,910	243	10,151	0.2	8	0.5	3,200	1	14	24	205	928	211	532	584	17,326	198
Jan	C	5	17,910	243	10,151	0.2	8	0.5	1,700	1	10	24	209	810	211	464	455	17,455	203
Jan	D/BN	5	32,510	442	17,140	0.2	2,029	0.5	3,300	1	21	44	376	810	211	464	156	32,354	374
Jan	AN/W	5	17,910	243	10,151	0.2	8	0.5	3,300	1	14	24	204	810	211	464	463	17,447	199
Feb	C	5	14,507	197	3,598	0.2	122	0.5	7,200	1	22	20	156	1,382	211	792	1,134	13,372	142
Feb	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	14,400	1	46	29	217	1,382	211	792	1,025	20,475	205
Feb	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	14,400	1	55	54	432	1,382	211	792	641	39,229	425
Mar	C	5	14,507	197	3,598	0.2	122	0.5	7,300	1	22	20	155	1,161	211	666	910	13,597	144
Mar	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	14,400	1	46	29	217	1,161	211	666	800	20,700	207
Mar	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	14,400	1	55	54	432	1,161	211	666	416	39,454	427
Apr	C	5	14,507	197	3,598	0.2	122	0.5	4,000	1	13	20	164	989	211	567	718	13,789	156
Apr	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	7,800	1	28	29	235	989	211	567	592	20,908	228
Apr	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	7,800	1	37	54	450	989	211	567	208	39,662	448
May	C	5	14,507	197	3,598	0.2	122	0.5	2,700	1	9	20	168	713	211	409	430	14,077	163
May	D/BN	5	21,500	292	9,150	0.2	1,240	0.5	5,300	1	21	29	242	713	211	409	298	21,202	238
May	AN/W	5	39,870	542	13,480	0.2	6,278	0.5	5,300	1	30	54	457	713	211	409	0	39,870	457
Jun	C	5	6,144	83	1,000	0.2	58	0.5	2,400	1	7	8	68	929	211	532	828	5,316	58
Jun	D/BN	5	16,000	217	6,220	0.2	412	0.5	4,600	1	16	22	179	929	211	532	630	15,370	171
Jun	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	4,600	1	20	31	262	929	211	532	483	22,517	256
Jul	C	5	6,144	83	1,000	0.2	58	0.5	2,000	1	6	8	69	762	211	437	656	5,489	61
Jul	D/BN	5	16,000	217	6,220	0.2	412	0.5	3,900	1	15	22	181	762	211	437	456	15,544	175
Jul	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	3,900	1	18	31	264	762	211	437	309	22,691	260
Aug	C	5	6,144	83	1,000	0.2	58	0.5	0	1	1	8	74	471	211	270	348	5,796	70
Aug	D/BN	5	16,000	217	6,220	0.2	412	0.5	0	1	4	22	192	471	211	270	139	15,861	190
Aug	AN/W	5	23,000	312	8,960	0.2	1,615	0.5	0	1	7	31	274	471	211	270	0	23,000	274

Wetland flow estimates are from D.G. Swain and N.W.T. Quin (April 1991).

** The equation is c16 ={ c15 + c10 - c3 x (1-MOS)}/{c14 - c1 x (1-MOS)}/Conversion factor : c = column

The equation is c18 ={ c17 x c1 x (1 - MOS) - c10 } x Conversion Factor

TABLE 22

Comparison of Paired San Joaquin River Flows
at Newman and Crows Landing (Crows)

Month	Newman Mean Flow AF/1000	Crows Mean Flow AF/1000	# of Samples	R2	Are Means Different by t-test?
Oct	36.4	33.6	10	0.398	No
Nov	33.2	37.6	12	0.667	No
Dec	34.6	39.7	12	0.857	Yes
Jan	32.6	43.0	8	0.354	No
Feb	32.6	43.0	8	0.508	Yes
Mar	31.4	41.1	7	0.614	Yes
Apr	33.2	40.5	10	0.904	Yes
May	33.3	38.9	11	0.833	Yes
Jun	32.9	32.2	12	0.717	No
Jul	33.2	36.3	17	0.821	No
Aug	34.4	37.1	17	0.759	No
Sep	34.5	35.2	14	0.723	No

* Newman flows were adjusted by Swain to reflect current management conditions. Crows Landing flows are from Table 6. Flows less than 57,000 acre-ft/month were compared.

TABLE 23

Effect of Considering Wetland Load Contributions and Tail Water Elimination on the Calculated Waste Load Allocation; 1 in 3 year Exceedance Rate of a Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	Adjustd Crows Flow Ac-Ft 3	TMML 1x3 lbs 4	Merced River Flow Acre-Ft 5	Merced River Conc. µg/L 6	SJR @ Lander Acre-Ft 7	SJR @ Lander Conc. µg/L 8	Wet-land Flow Acre-Ft 9	Wet-land Conc µg/L 10	Bkgnd Load 5x6+7x8 +9x10 lbs 11	MOS (3) x 10% lbs 12	WLA DSA 4-11-12 lbs 13
Sept	C	5	11,583	10,895	148	4,242	0.2	70	0.5	1,000	1	5	15	128
Sept	D/BN	5	23,660	22,972	312	9,830	0.2	2,073	0.5	1,900	1	13	31	268
Sept	AN/W	5	11,583	10,895	148	4,242	0.2	70	0.5	1,900	1	8	15	126
Oct	C	5	11,583	10,844	147	4,242	0.2	70	0.5	1,700	1	7	15	126
Oct	D/BN	5	23,660	22,921	311	9,830	0.2	2,073	0.5	3,300	1	17	31	263
Oct	AN/W	5	11,583	10,844	147	4,242	0.2	70	0.5	3,300	1	11	15	121
Nov	C	5	11,583	10,607	144	4,242	0.2	70	0.5	1,700	1	7	14	123
Nov	D/BN	5	23,660	22,683	308	9,830	0.2	2,073	0.5	3,300	1	17	31	260
Nov	AN/W	5	11,583	10,607	144	4,242	0.2	70	0.5	3,300	1	11	14	118
Dec	C	5	17,910	17,421	237	10,151	0.2	8	0.5	1,600	1	10	24	203
Dec	D/BN	5	32,510	32,021	435	17,140	0.2	2,029	0.5	3,200	1	21	43	371
Dec	AN/W	5	17,910	17,421	237	10,151	0.2	8	0.5	3,200	1	14	24	199
Jan	C	5	17,910	16,754	228	10,151	0.2	8	0.5	1,700	1	10	23	195
Jan	D/BN	5	32,510	31,354	426	17,140	0.2	2,029	0.5	3,300	1	21	43	362
Jan	AN/W	5	17,910	16,754	228	10,151	0.2	8	0.5	3,300	1	14	23	190
Feb	C	5	14,507	12,480	170	3,598	0.2	122	0.5	7,200	1	22	17	131
Feb	D/BN	5	21,500	19,474	265	9,150	0.2	1,240	0.5	14,400	1	46	26	192
Feb	AN/W	5	39,870	37,844	514	13,480	0.2	6,278	0.5	14,400	1	55	51	408
Mar	C	5	14,507	12,105	164	3,598	0.2	122	0.5	7,300	1	22	16	126
Mar	D/BN	5	21,500	19,099	259	9,150	0.2	1,240	0.5	14,400	1	46	26	188
Mar	AN/W	5	39,870	37,469	509	13,480	0.2	6,278	0.5	14,400	1	55	51	403
Apr	C	5	14,507	12,679	172	3,598	0.2	122	0.5	4,000	1	13	17	142
Apr	D/BN	5	21,500	19,672	267	9,150	0.2	1,240	0.5	7,800	1	28	27	213
Apr	AN/W	5	39,870	38,042	517	13,480	0.2	6,278	0.5	7,800	1	37	52	428
May	C	5	14,507	12,637	172	3,598	0.2	122	0.5	2,700	1	9	17	145
May	D/BN	5	21,500	19,630	267	9,150	0.2	1,240	0.5	5,300	1	21	27	219
May	AN/W	5	39,870	38,000	516	13,480	0.2	6,278	0.5	5,300	1	30	52	434
Jun	C	5	6,144	4,157	56	1,000	0.2	58	0.5	2,400	1	7	6	44
Jun	D/BN	5	16,000	14,012	190	6,220	0.2	412	0.5	4,600	1	16	19	155
Jun	AN/W	5	23,000	21,012	285	8,960	0.2	1,615	0.5	4,600	1	20	29	237
Jul	C	5	6,144	3,567	48	1,000	0.2	58	0.5	2,000	1	6	5	38
Jul	D/BN	5	16,000	13,423	182	6,220	0.2	412	0.5	3,900	1	15	18	150
Jul	AN/W	5	23,000	20,423	277	8,960	0.2	1,615	0.5	3,900	1	18	28	232
Aug	C	5	6,144	3,696	50	1,000	0.2	58	0.5	0	1	1	5	45
Aug	D/BN	5	16,000	13,552	184	6,220	0.2	412	0.5	0	1	4	18	162
Aug	AN/W	5	23,000	20,552	279	8,960	0.2	1,615	0.5	0	1	7	28	244

TABLE 24

Effect of Considering Increased Wetland Flow on the Calculated Waste Load Allocation; 1 in 3 year Exceedance Rate of a Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	Adjustd Crows Flow Ac-Ft 3	TMML 1x3 lbs 4	Merced River Flow Acre-Ft 5	Merced River Conc. µg/L 6	SJR@ Lander Acre-Ft 7	SJR@ Lander Conc. µg/L 8	Wet-land Flow Acre-Ft 9	Wet-land Conc µg/L 10	Bkgnd Load 5x6+7x8 +9x10 lbs 11	MOS (3) x 10% lbs 12	WLA DSA 4-11-12 lbs 13
Sept	C	5	11,583	13,583	185	4,242	0.2	70	0.5	3,000	1	11	18	156
Sept	D/BN	5	23,660	25,660	349	9,830	0.2	2,073	0.5	3,900	1	19	35	295
Sept	AN/W	5	11,583	13,583	185	4,242	0.2	70	0.5	3,900	1	13	18	153
Oct	C	5	11,583	13,583	185	4,242	0.2	70	0.5	3,700	1	12	18	154
Oct	D/BN	5	23,660	25,660	349	9,830	0.2	2,073	0.5	5,300	1	23	35	291
Oct	AN/W	5	11,583	13,583	185	4,242	0.2	70	0.5	5,300	1	17	18	149
Nov	C	5	11,583	13,583	185	4,242	0.2	70	0.5	3,700	1	12	18	154
Nov	D/BN	5	23,660	25,660	349	9,830	0.2	2,073	0.5	5,300	1	23	35	291
Nov	AN/W	5	11,583	13,583	185	4,242	0.2	70	0.5	5,300	1	17	18	149
Dec	C	5	17,910	19,910	270	10,151	0.2	8	0.5	3,600	1	15	27	228
Dec	D/BN	5	32,510	34,510	469	17,140	0.2	2,029	0.5	5,200	1	26	47	396
Dec	AN/W	5	17,910	19,910	270	10,151	0.2	8	0.5	5,200	1	20	27	224
Jan	C	5	17,910	19,910	270	10,151	0.2	8	0.5	3,700	1	16	27	228
Jan	D/BN	5	32,510	34,510	469	17,140	0.2	2,029	0.5	5,300	1	26	47	395
Jan	AN/W	5	17,910	19,910	270	10,151	0.2	8	0.5	5,300	1	20	27	223
Feb	C	5	14,507	17,507	238	3,598	0.2	122	0.5	10,200	1	30	24	184
Feb	D/BN	5	21,500	24,500	333	9,150	0.2	1,240	0.5	17,400	1	54	33	246
Feb	AN/W	5	39,870	42,870	582	13,480	0.2	6,278	0.5	17,400	1	63	58	461
Mar	C	5	14,507	22,007	299	3,598	0.2	122	0.5	14,800	1	42	30	227
Mar	D/BN	5	21,500	29,000	394	9,150	0.2	1,240	0.5	21,900	1	66	39	288
Mar	AN/W	5	39,870	47,370	643	13,480	0.2	6,278	0.5	21,900	1	75	64	504
Apr	C	5	14,507	22,007	299	3,598	0.2	122	0.5	11,500	1	33	30	236
Apr	D/BN	5	21,500	29,000	394	9,150	0.2	1,240	0.5	15,300	1	48	39	306
Apr	AN/W	5	39,870	47,370	643	13,480	0.2	6,278	0.5	15,300	1	57	64	522
May	C	5	14,507	16,507	224	3,598	0.2	122	0.5	4,700	1	15	22	187
May	D/BN	5	21,500	23,500	319	9,150	0.2	1,240	0.5	7,300	1	26	32	261
May	AN/W	5	39,870	41,870	569	13,480	0.2	6,278	0.5	7,300	1	36	57	476
Jun	C	5	6,144	8,144	111	1,000	0.2	58	0.5	4,400	1	13	11	87
Jun	D/BN	5	16,000	18,000	244	6,220	0.2	412	0.5	6,600	1	22	24	198
Jun	AN/W	5	23,000	25,000	340	8,960	0.2	1,615	0.5	6,600	1	25	34	281
Jul	C	5	6,144	8,144	111	1,000	0.2	58	0.5	4,000	1	11	11	88
Jul	D/BN	5	16,000	18,000	244	6,220	0.2	412	0.5	5,900	1	20	24	200
Jul	AN/W	5	23,000	25,000	340	8,960	0.2	1,615	0.5	5,900	1	23	34	283
Aug	C	5	6,144	8,144	111	1,000	0.2	58	0.5	2,000	1	6	11	94
Aug	D/BN	5	16,000	18,000	244	6,220	0.2	412	0.5	2,000	1	9	24	211
Aug	AN/W	5	23,000	25,000	340	8,960	0.2	1,615	0.5	2,000	1	12	34	293

Annual wetland flows are increased from 33,300 acre-ft to 69,300 acre-ft for critical years and from 65,400 acre-ft to 101,400 acre-ft for other year types.

TABLE 25

Effectof Considering Adjustments in Merced River Flow in Response to a 440 EC Objective in the San Joaquin River on the Calculated Waste Load Allocation ; 1 in 3 year Exceedance Rate of a Monthly Mean Water Quality Objective

Time Period	Year Type	WQO µg/L 1	Crows Flow Ac-Ft 2	Adjustd Crows Flow Ac-Ft 3	TMML 1x3 lbs 4	Merced River Flow Acre-Ft 5	Merced River Conc. µg/L 6	SJR@ Lander Acre-Ft 7	SJR@ Lander Conc. µg/L 8	Wet-land Flow Acre-Ft 9	Wet-land Conc µg/L 10	Bkgnd Load 5x6+7x8 +9x10 lbs 11	MOS (3) x 10% lbs 12	WLA DSA 4-11-12 lbs 13
Sept	C	5	11,583	10,583	144	3,242	0.2	70	0.5	1,000	1	5	14	125
Sept	D/BN	5	23,660	22,660	308	8,830	0.2	2,073	0.5	1,900	1	13	31	264
Sept	AN/W	5	11,583	10,583	144	3,242	0.2	70	0.5	1,900	1	7	14	122
Oct	C	5	11,583	10,583	144	3,242	0.2	70	0.5	1,700	1	6	14	123
Oct	D/BN	5	23,660	22,660	308	8,830	0.2	2,073	0.5	3,300	1	17	31	260
Oct	AN/W	5	11,583	10,583	144	3,242	0.2	70	0.5	3,300	1	11	14	119
Nov	C	5	11,583	10,583	144	3,242	0.2	70	0.5	1,700	1	6	14	123
Nov	D/BN	5	23,660	22,660	308	8,830	0.2	2,073	0.5	3,300	1	17	31	260
Nov	AN/W	5	11,583	10,583	144	3,242	0.2	70	0.5	3,300	1	11	14	119
Dec	C	5	17,910	16,910	230	9,151	0.2	8	0.5	1,600	1	9	23	197
Dec	D/BN	5	32,510	31,510	428	16,140	0.2	2,029	0.5	3,200	1	20	43	365
Dec	AN/W	5	17,910	16,910	230	9,151	0.2	8	0.5	3,200	1	14	23	193
Jan	C	5	17,910	16,910	230	9,151	0.2	8	0.5	1,700	1	10	23	197
Jan	D/BN	5	32,510	31,510	428	16,140	0.2	2,029	0.5	3,300	1	20	43	365
Jan	AN/W	5	17,910	16,910	230	9,151	0.2	8	0.5	3,300	1	14	23	193
Feb	C	5	14,507	11,507	156	598	0.2	122	0.5	7,200	1	20	16	121
Feb	D/BN	5	21,500	18,500	251	6,150	0.2	1,240	0.5	14,400	1	44	25	182
Feb	AN/W	5	39,870	36,870	501	10,480	0.2	6,278	0.5	14,400	1	53	50	397
Mar	C	5	14,507	11,507	156	598	0.2	122	0.5	7,300	1	20	16	120
Mar	D/BN	5	21,500	18,500	251	6,150	0.2	1,240	0.5	14,400	1	44	25	182
Mar	AN/W	5	39,870	36,870	501	10,480	0.2	6,278	0.5	14,400	1	53	50	397
Apr	C	5	14,507	21,507	292	10,598	0.2	122	0.5	4,000	1	17	29	246
Apr	D/BN	5	21,500	28,500	387	16,150	0.2	1,240	0.5	7,800	1	32	39	317
Apr	AN/W	5	39,870	46,870	637	20,480	0.2	6,278	0.5	7,800	1	41	64	532
May	C	5	14,507	21,507	292	10,598	0.2	122	0.5	2,700	1	13	29	250
May	D/BN	5	21,500	28,500	387	16,150	0.2	1,240	0.5	5,300	1	25	39	324
May	AN/W	5	39,870	46,870	637	20,480	0.2	6,278	0.5	5,300	1	34	64	539
Jun	C	5	6,144	5,144	70	0	0.2	58	0.5	2,400	1	7	7	56
Jun	D/BN	5	16,000	15,000	204	5,220	0.2	412	0.5	4,600	1	16	20	167
Jun	AN/W	5	23,000	22,000	299	7,960	0.2	1,615	0.5	4,600	1	19	30	250
Jul	C	5	6,144	5,144	70	0	0.2	58	0.5	2,000	1	6	7	57
Jul	D/BN	5	16,000	15,000	204	5,220	0.2	412	0.5	3,900	1	14	20	169
Jul	AN/W	5	23,000	22,000	299	7,960	0.2	1,615	0.5	3,900	1	17	30	252
Aug	C	5	6,144	5,144	70	0	0.2	58	0.5	0	1	0	7	63
Aug	D/BN	5	16,000	15,000	204	5,220	0.2	412	0.5	0	1	3	20	180
Aug	AN/W	5	23,000	22,000	299	7,960	0.2	1,615	0.5	0	1	7	30	262

Annual wetland flows are increased from 33,300 acre-ft to 69,300 acre-ft for critical years and from 65,400 acre-ft to 101,400 acre-ft for other year types.

TABLE 26

CALIFORNIA COOPERATIVE SNOW SURVEY
FORECAST OF SACRAMENTO RIVER INDEX, WATER YEAR 1993-94
IN MILLION ACRE FEET / PERCENT OF AVE

1 JANUARY 1994

Probability of exceedence	99%	90%	75%	50%	25%	10%
Total water year runoff	6.3	7.9	9.6	13.0	17.1	21.4
Percent of average	34%	43%	52%	71%	93%	116%

1994 Runoff to Date = 1.6 MAF (est)
1993 Runoff to Date = 1.9 MAF

The Sacramento River Index is the sum of unimpaired runoff from the Sacramento River at Bend Bridge, Feather River inflow to Oroville, Yuba River at Smartville, and American River inflow to Folsom.

1941-90 average = 18.4 MAF

D-1485 Year Classification

Wet:	19.6 or more
Above Normal:	less than 19.6 and more than 15.7
Below Normal:	less than 15.7 and more than 12.5
Dry:	less than 12.5 and more than 10.2
Critical:	10.2 or less

From the California Department of Water Resources, 1994.

TABLE 27

Effect of Changing the Water Year Classification on Flow in the San Joaquin River at Crows Landing (Water Years 1970-91)

(a)
Statistics are Flow in 1,000s of Acre-Feet

January-December WY Classification		
WY Type	Mean	Std Dev
Critical	32.7	14.1
Dry/Below Normal	46.6	17.4
Above Normal/Wet	210	282

October-September WY Classification		
WY Type	Mean	Std Dev
Critical	35.5	15.9
Dry/Below Normal	49.4	20.8
Above Normal/Wet	208	283

Effect of Changing the Water Year Classification on the TMML in the San Joaquin River at Crows Landing (Water Years 1970-91)

(b)
TMML in Pounds of Selenium, 1 in 3 year
Exceedance Rate, 5 µg/L Monthly Objective

WY Type	Water Year	
	Jan-Dec	Oct-Sep
Critical	1,851	1,997
Dry/Below Normal	3,667	3,667
Above Normal/Wet	5,332	4,062

FIGURE 1 (a)

Location Map

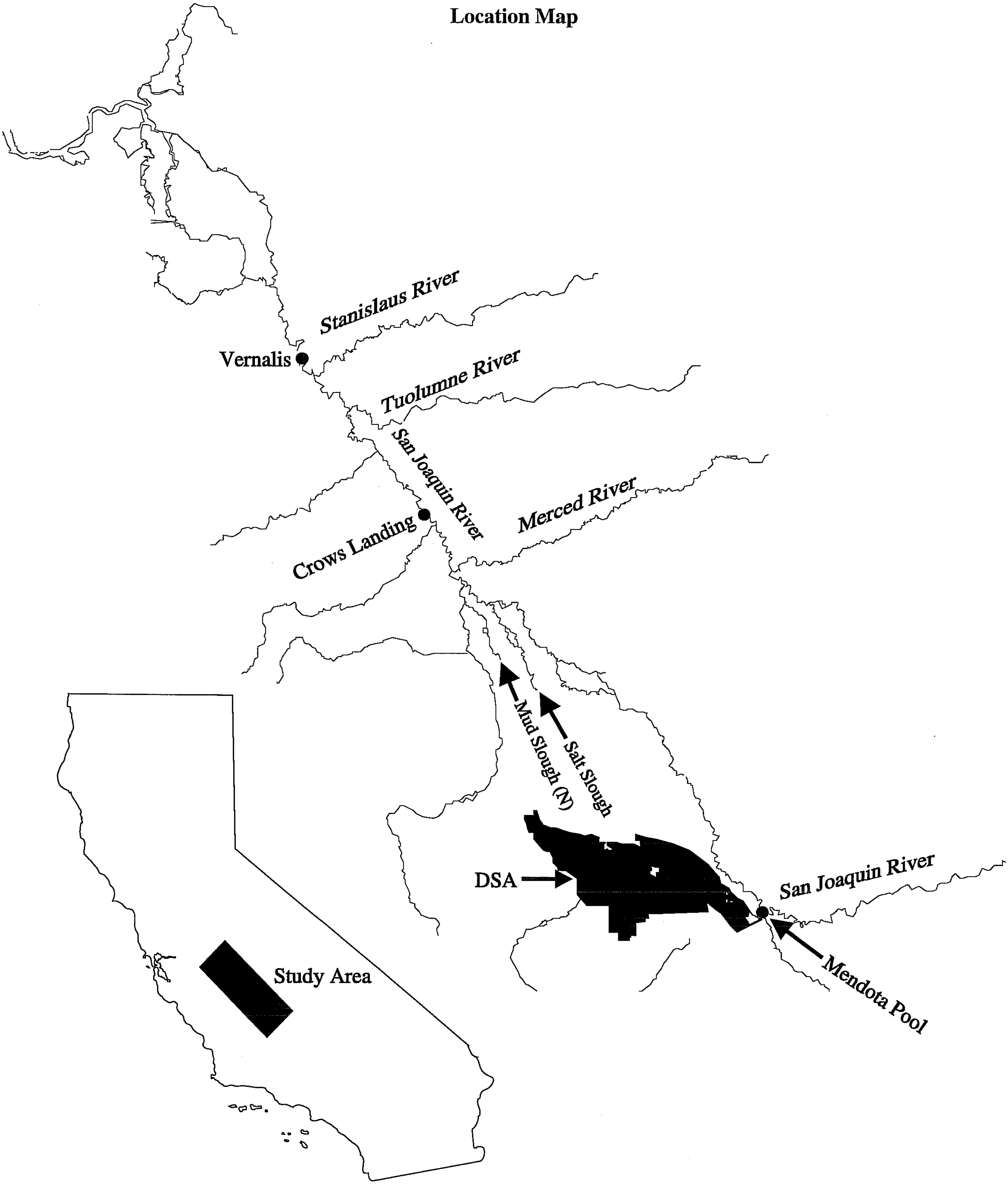


FIGURE 1 (b)

Schematic of Middle and Lower San Joaquin River Basin

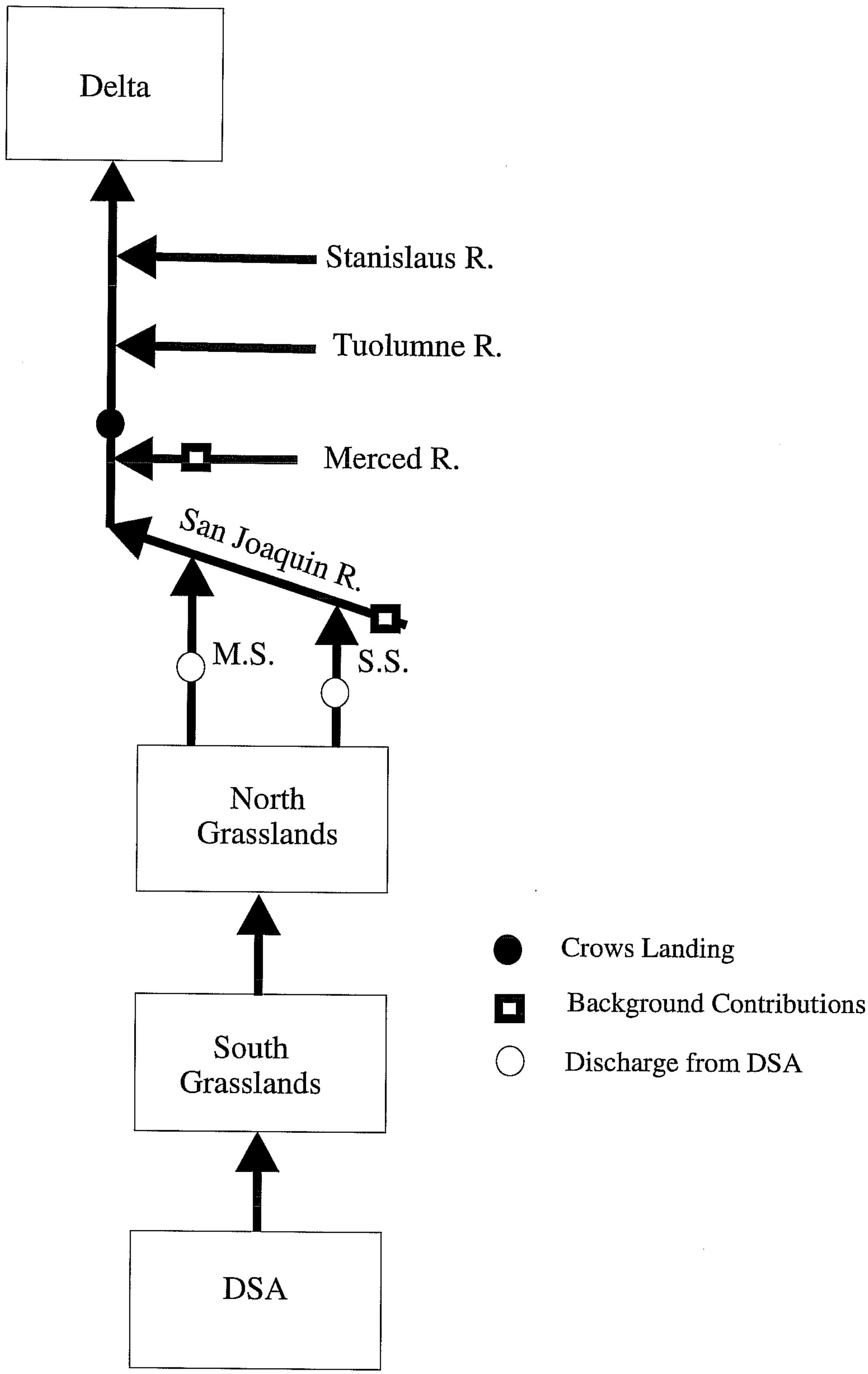


FIGURE 2

Annual Selenium Loads and Concentrations for the DSA and Mud Slough (north) and Salt Slough

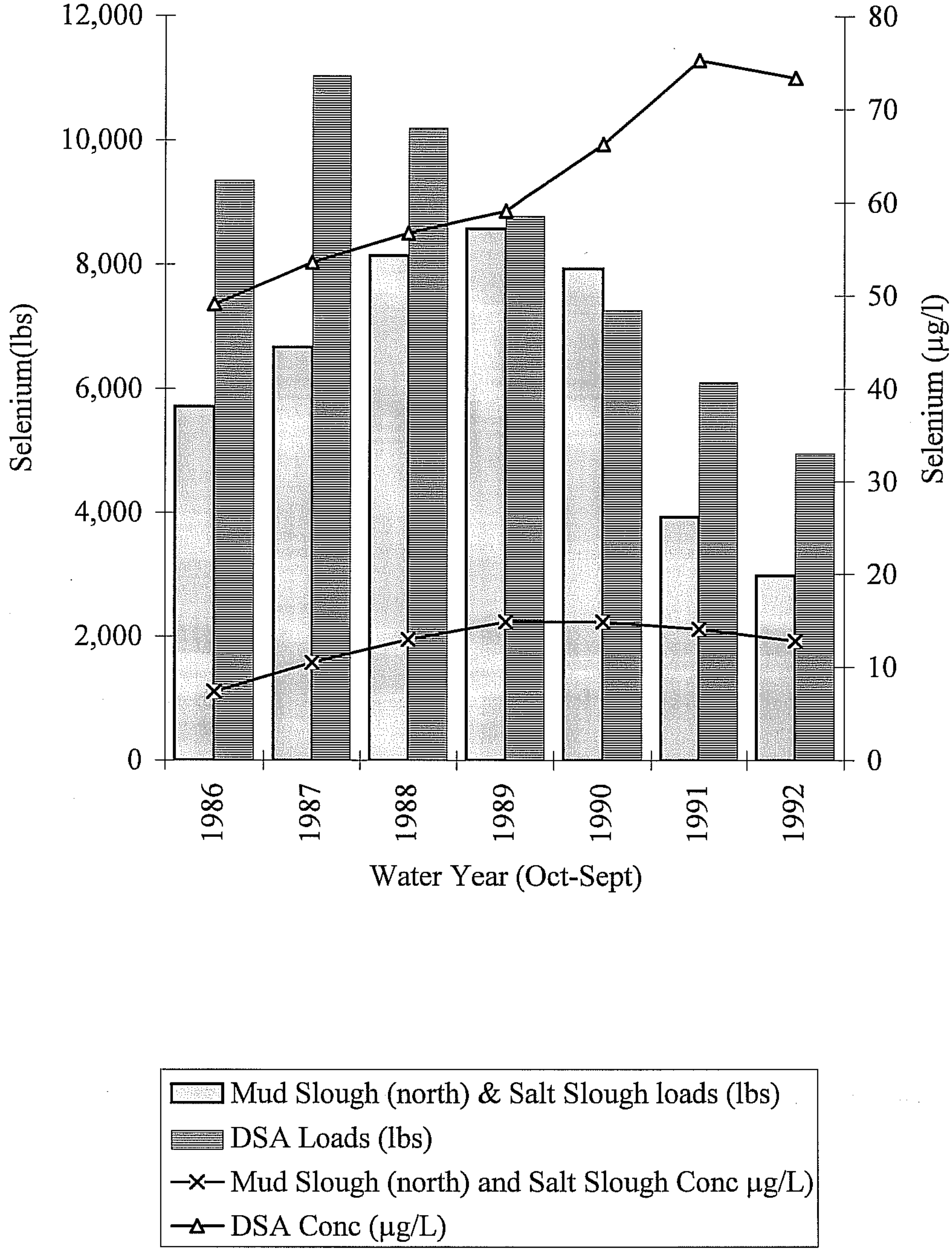


FIGURE 3

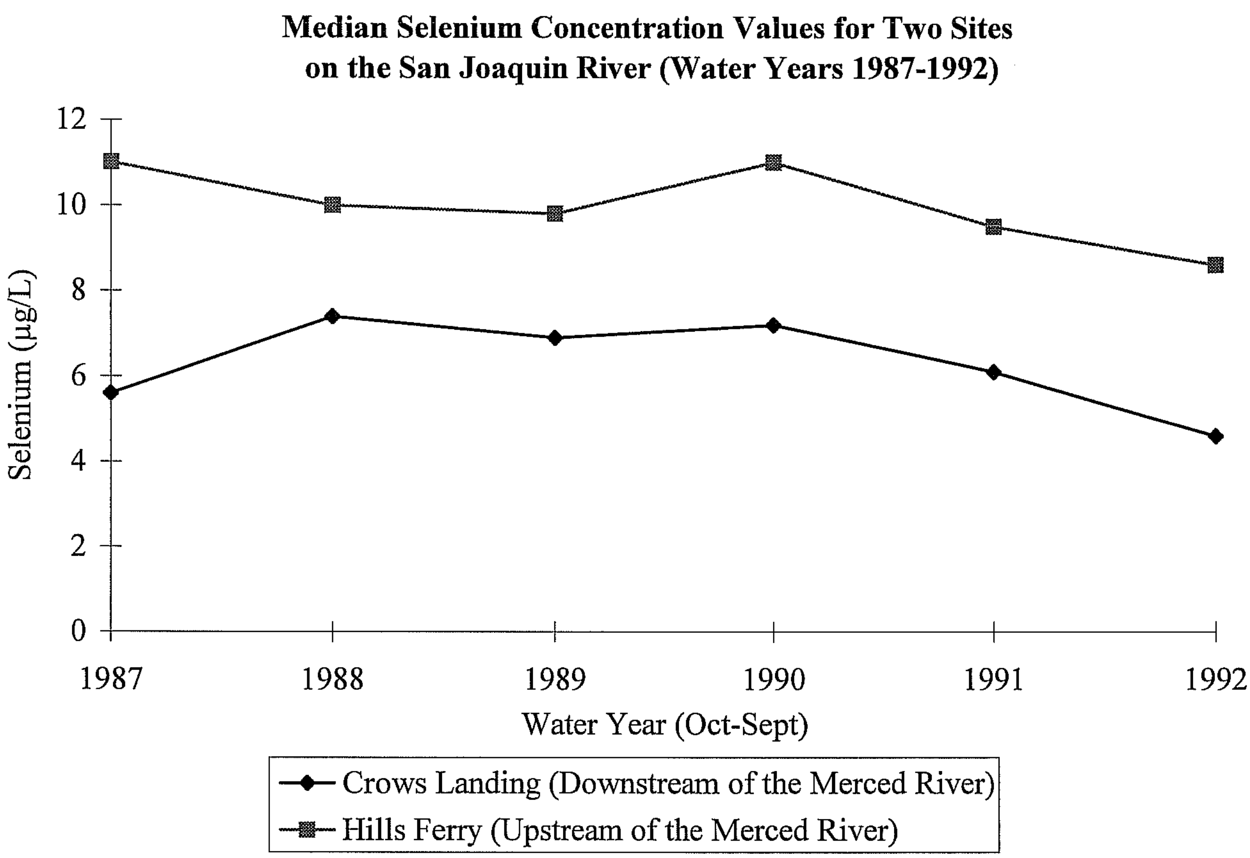

Median Selenium Concentration Values for Two Sites
on the San Joaquin River (Water Years 1987-1992)
Selenium (µg/L)
12
10
8
6
4
2
0
1987
1988
1989
1990
1991
1992
Water Year (Oct-Sept)
Crows Landing (Downstream of the Merced River)
Hills Ferry (Upstream of the Merced River)

FIGURE 4

San Joaquin River (SJR) Average Monthly Flow (Water Years 1970-91) and Selenium Load from the Drainage Study Area (Water Years 1986-91)

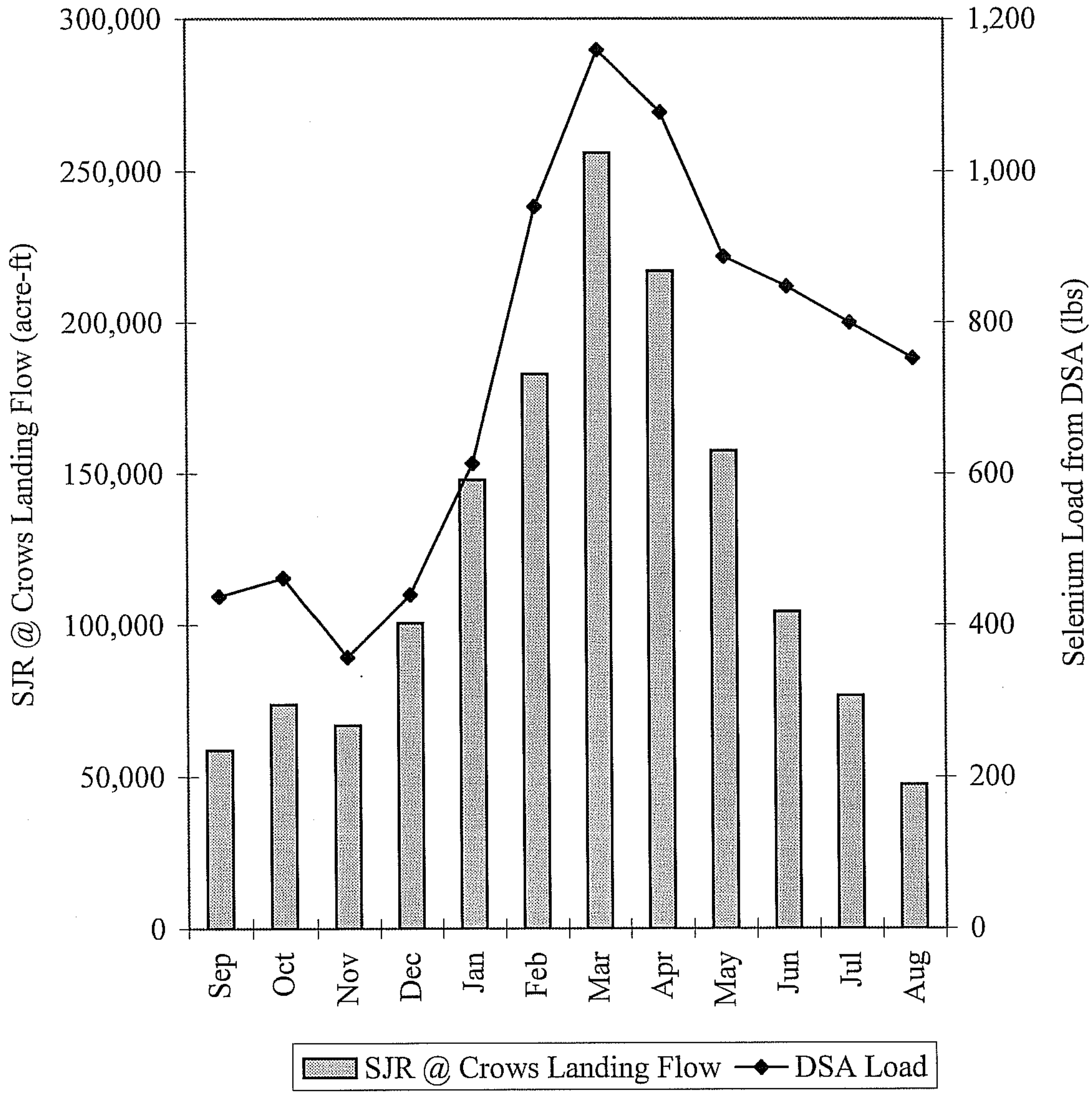


FIGURE 5

Process Diagram for Determining Allowable Loads with SJRIO-2

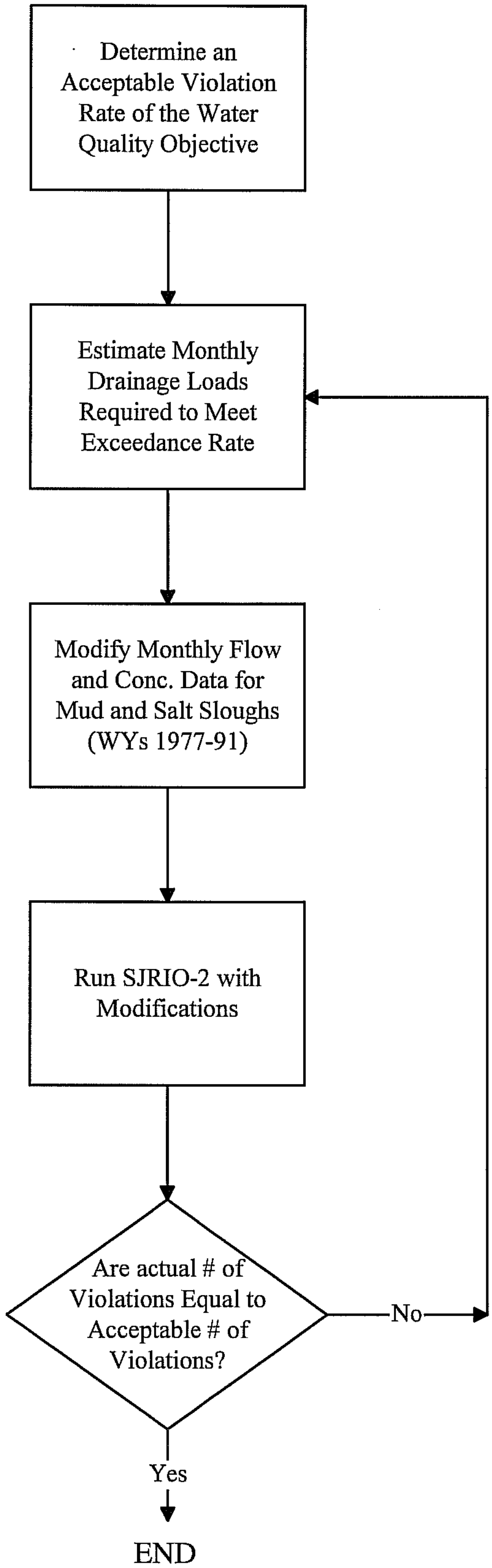
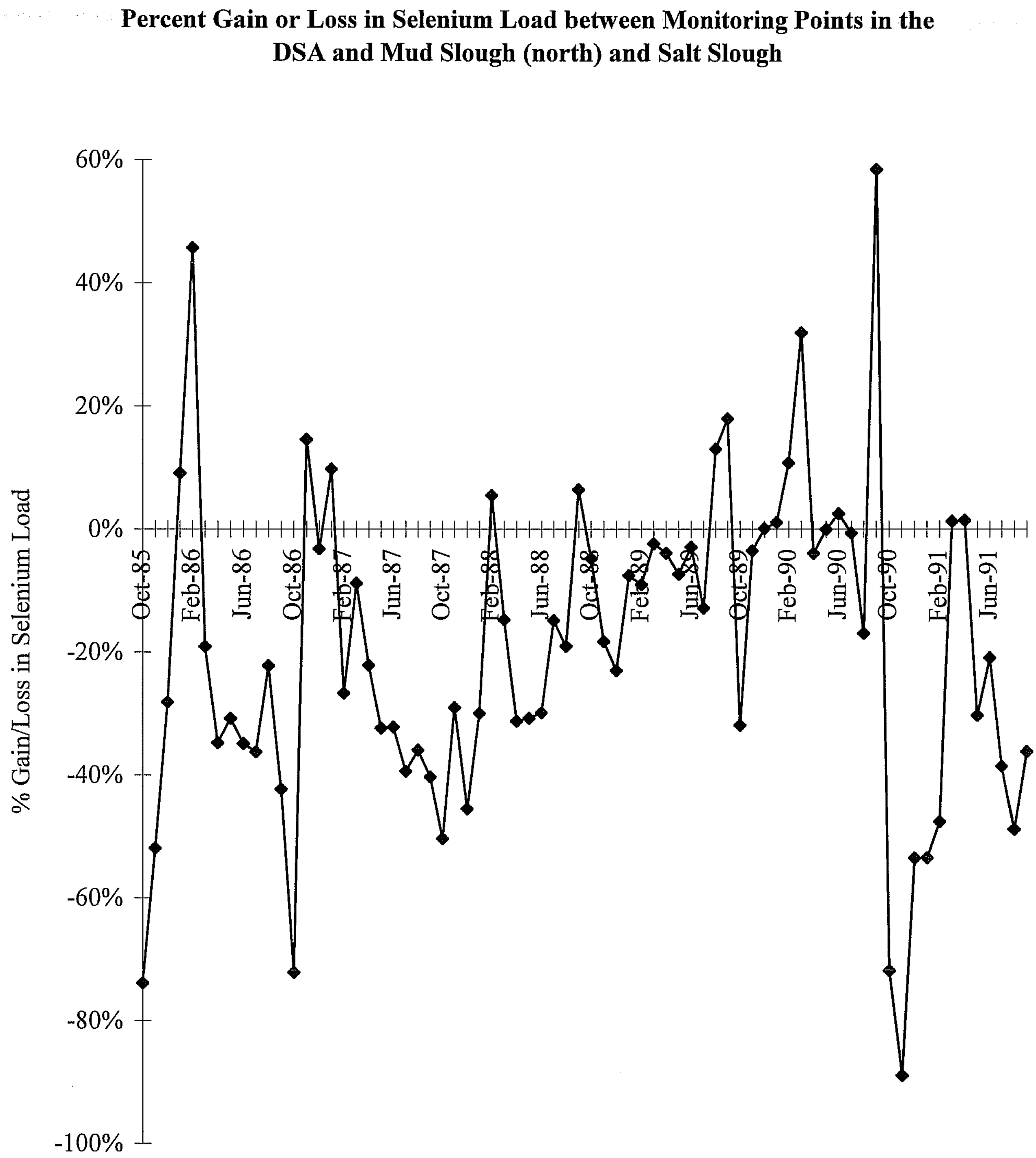


FIGURE 6



Percent Gain or Loss in Selenium Load between Monitoring Points in the DSA and Mud Slough (north) and Salt Slough
60%
40%
20%
0%
-20%
-40%
-60%
-80%
-100%
% Gain/Loss in Selenium Load
Oct-85
Feb-86
Jun-86
Oct-86
Feb-87
Jun-87
Oct-87
Feb-88
Jun-88
Oct-88
Feb-89
Jun-89
Oct-89
Feb-90
Jun-90
Oct-90
Feb-91
Jun-91

FIGURE 7

Selenium Load for Crows Landing on the San Joaquin River (SJR) and
Mud Slough (north) and Salt Slough

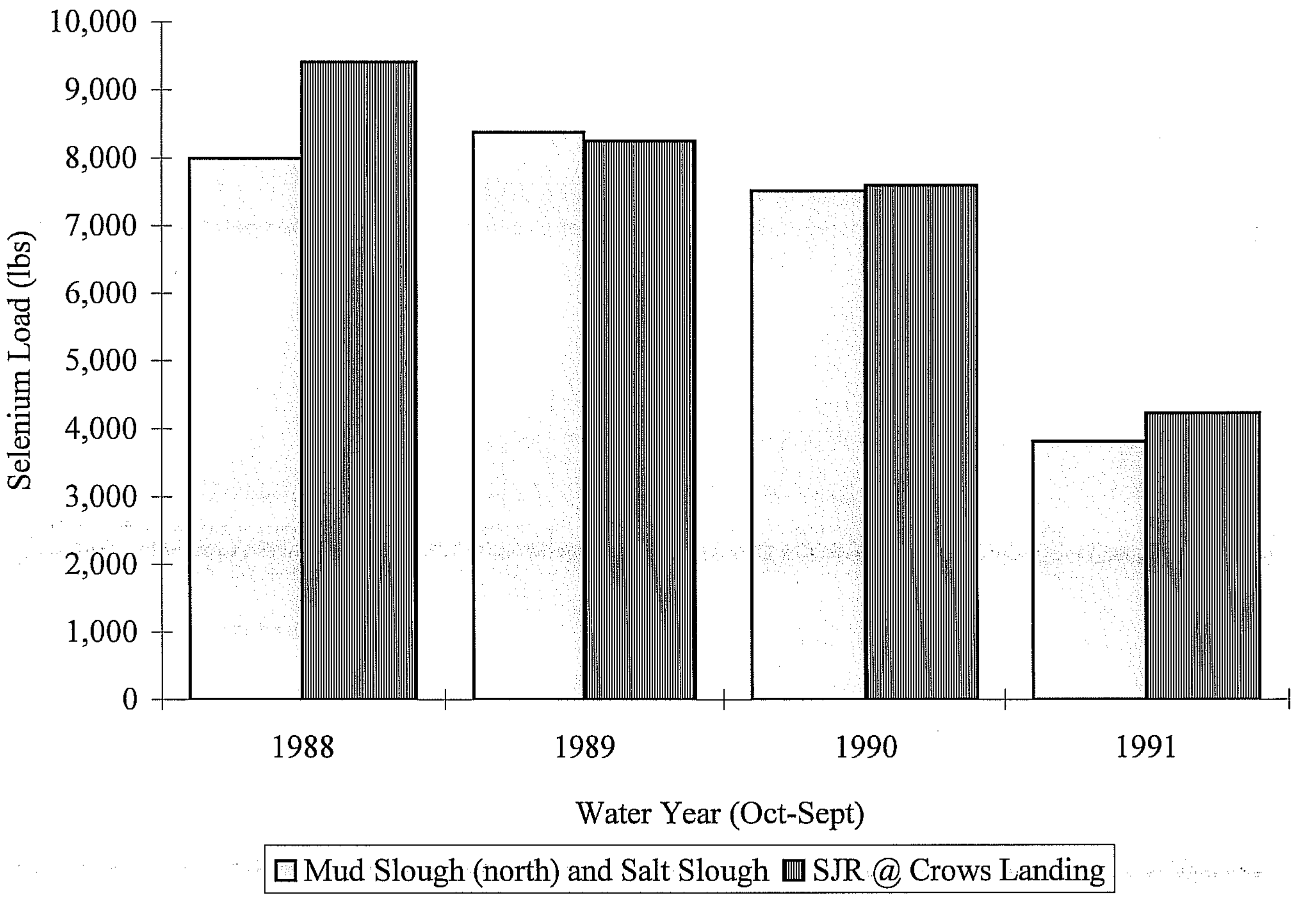


FIGURE 8

TMML SJR MODEL PROCEDURE

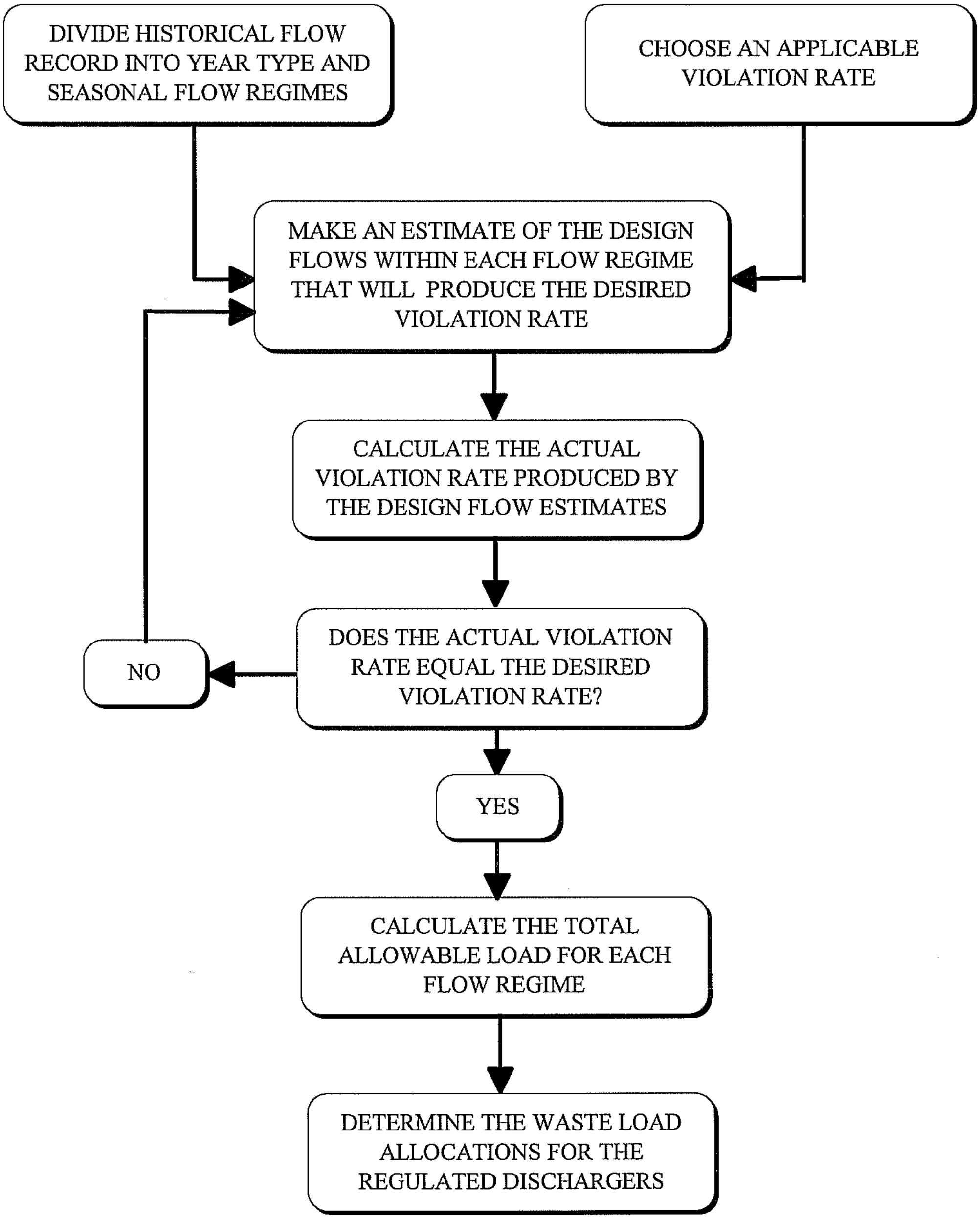


FIGURE 9

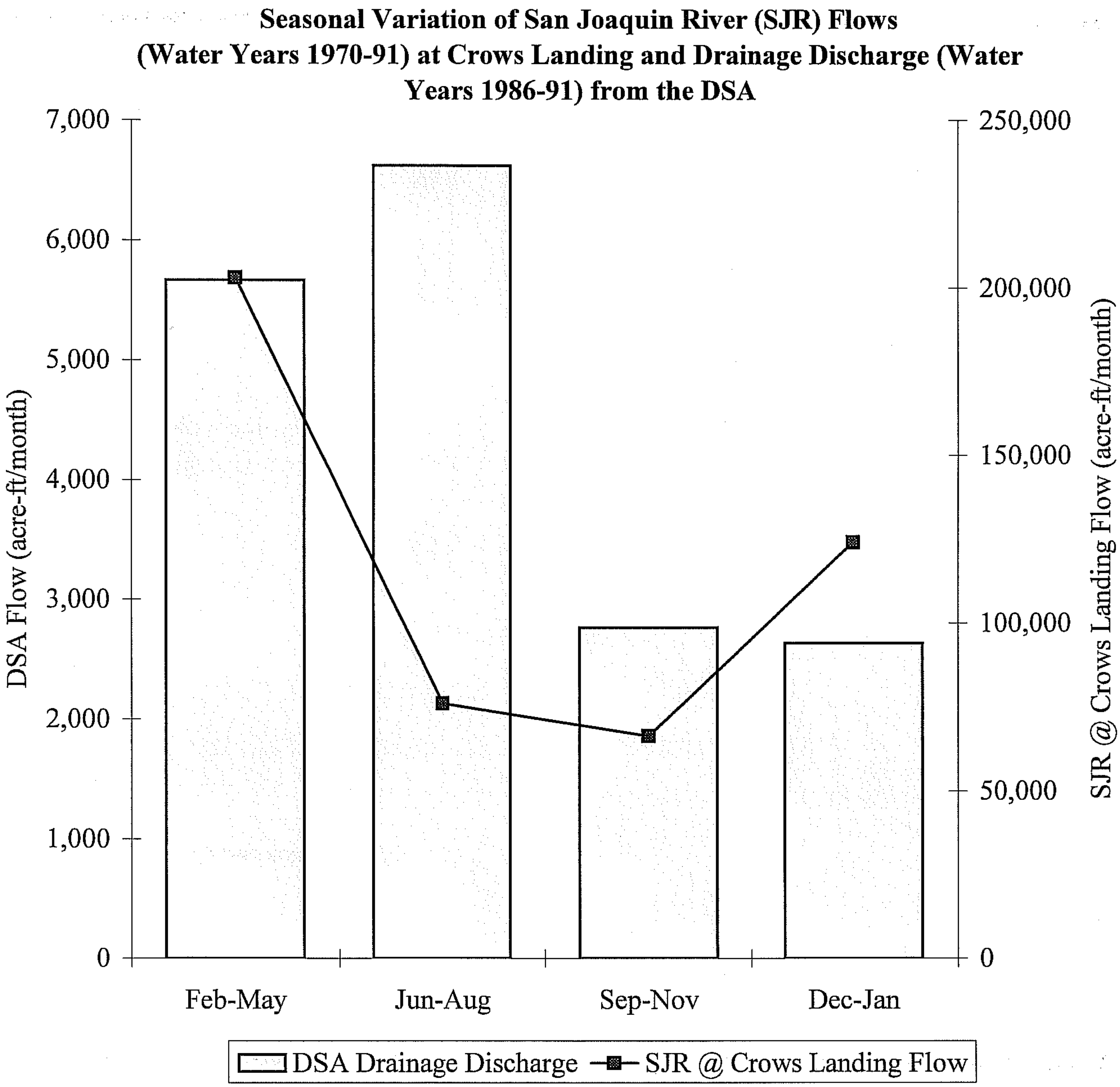
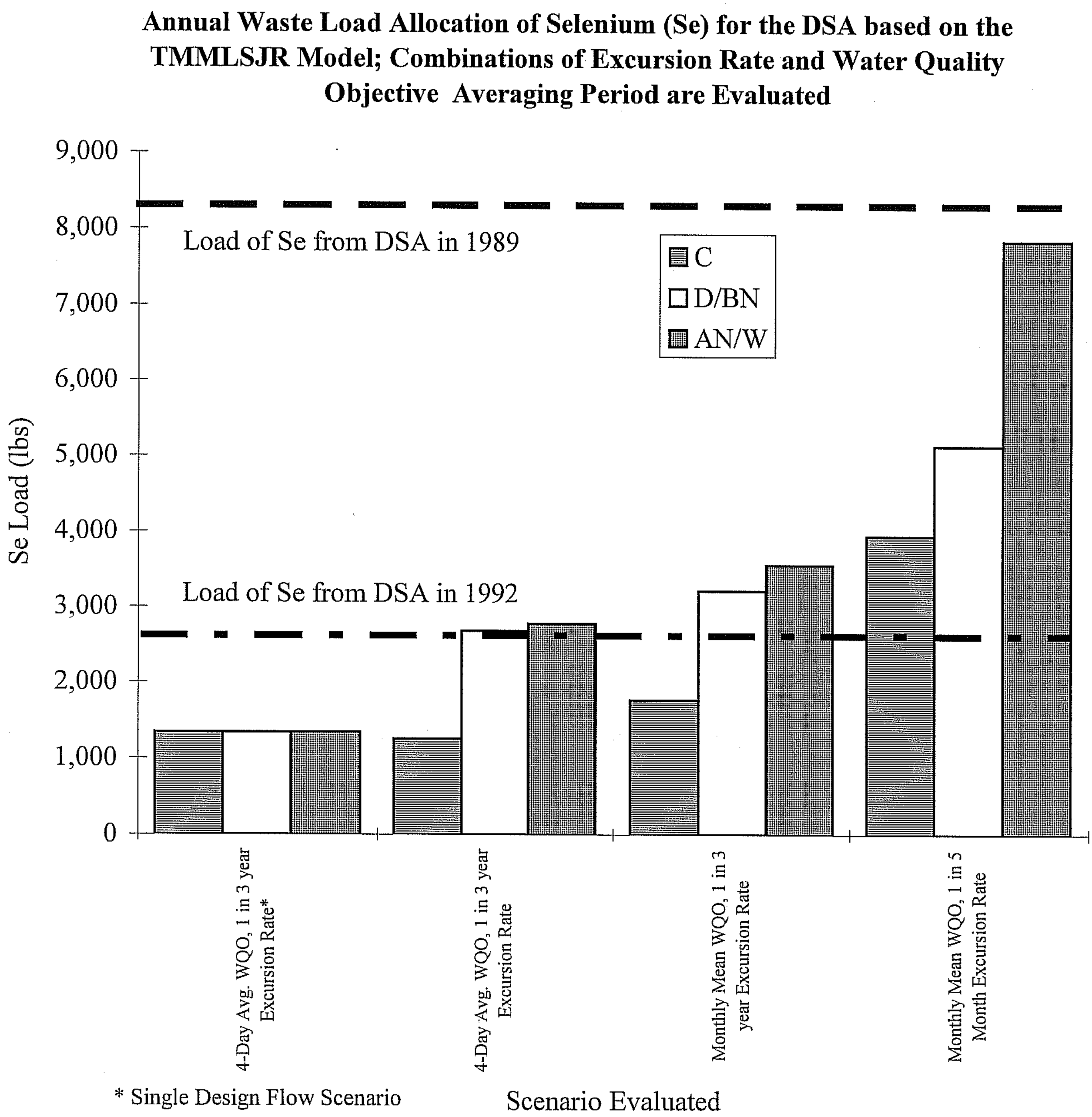

Seasonal Variation of San Joaquin River (SJR) Flows (Water Years 1970-91) at Crows Landing and Drainage Discharge (Water Years 1986-91) from the DSA
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
DSA Flow (acre-ft/month)
250,000
200,000
150,000
100,000
50,000
0
SJR @ Crows Landing Flow (acre-ft/month)
Feb-May
Jun-Aug
Sep-Nov
Dec-Jan
DSA Drainage Discharge
SJR @ Crows Landing Flow

FIGURE 10



Annual Waste Load Allocation of Selenium (Se) for the DSA based on the TMMLSJR Model; Combinations of Excursion Rate and Water Quality Objective Averaging Period are Evaluated
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Se Load (lbs)
Load of Se from DSA in 1989
Load of Se from DSA in 1992
C
D/BN
AN/W
4-Day Avg. WQO, 1 in 3 year Excursion Rate*
4-Day Avg. WQO, 1 in 3 year Excursion Rate
Monthly Mean WQO, 1 in 3 year Excursion Rate
Monthly Mean WQO, 1 in 5 Month Excursion Rate
* Single Design Flow Scenario
Scenario Evaluated

FIGURE 11

Comparison of Waste Load Allocation for a 1 in 5 Month Excursion Rate (Critical Year Type) to Actual Load from Mud Slough (north) and Salt Slough

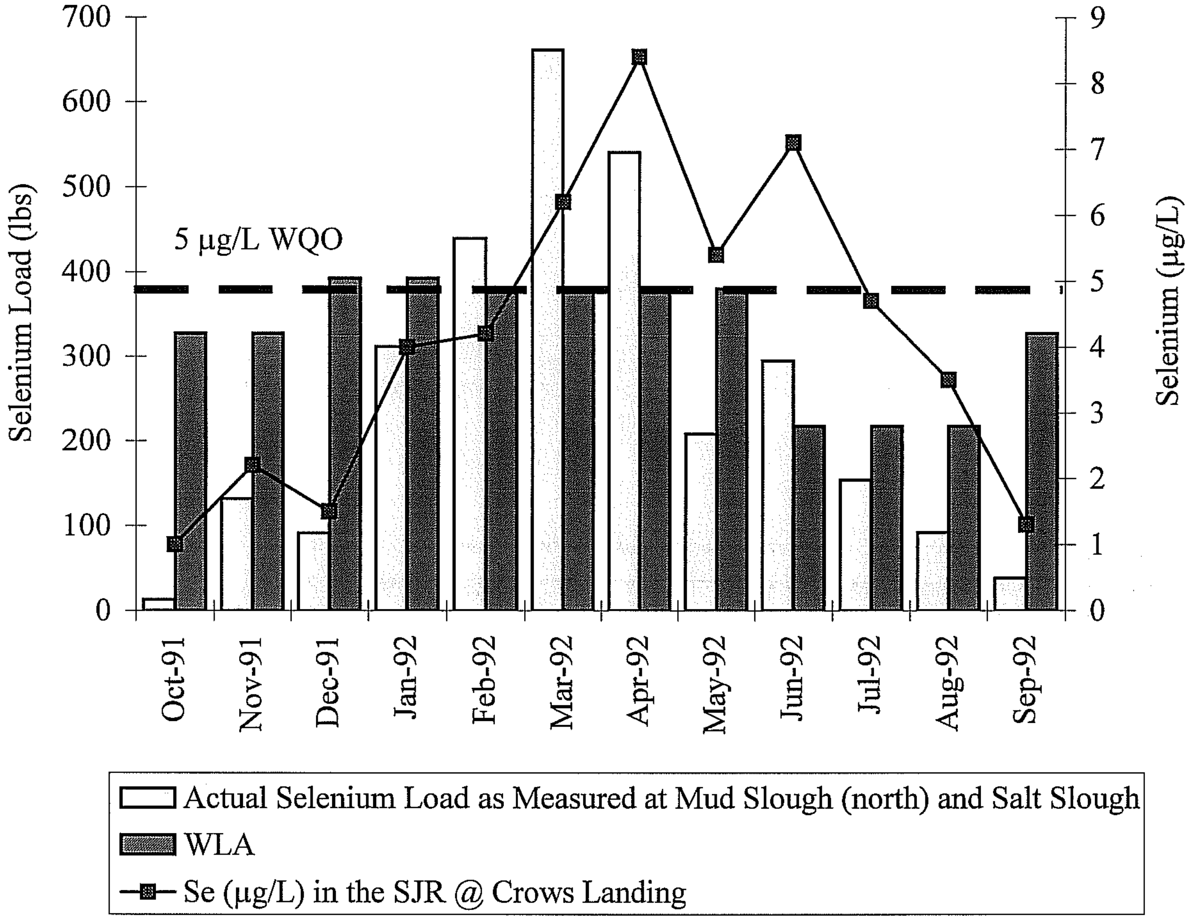
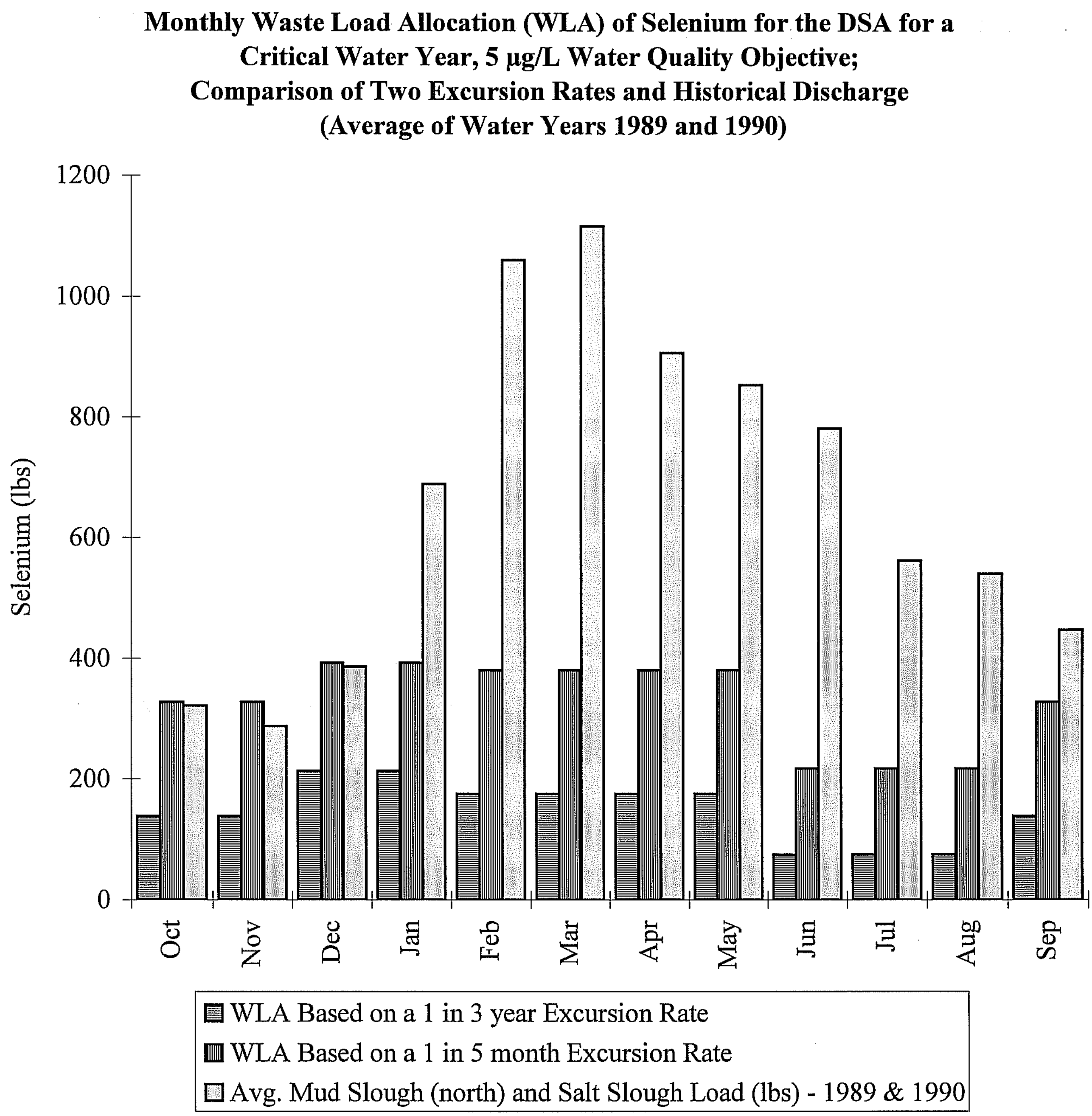


FIGURE 12



Monthly Waste Load Allocation (WLA) of Selenium for the DSA for a Critical Water Year, 5 µg/L Water Quality Objective; Comparison of Two Excursion Rates and Historical Discharge (Average of Water Years 1989 and 1990)
Selenium (lbs)
1200
1000
800
600
400
200
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
WLA Based on a 1 in 3 year Excursion Rate
WLA Based on a 1 in 5 month Excursion Rate
Avg. Mud Slough (north) and Salt Slough Load (lbs) - 1989 & 1990

FIGURE 13

Monthly Waste Load Allocations (WLA) of Selenium for the DSA for an Above Normal/Wet Water Year, 5 µg/L Monthly Mean Water Quality Objective; Comparison of Two Excursion Rates and Historical Discharge (Average of Water Years 1989 and 1990)

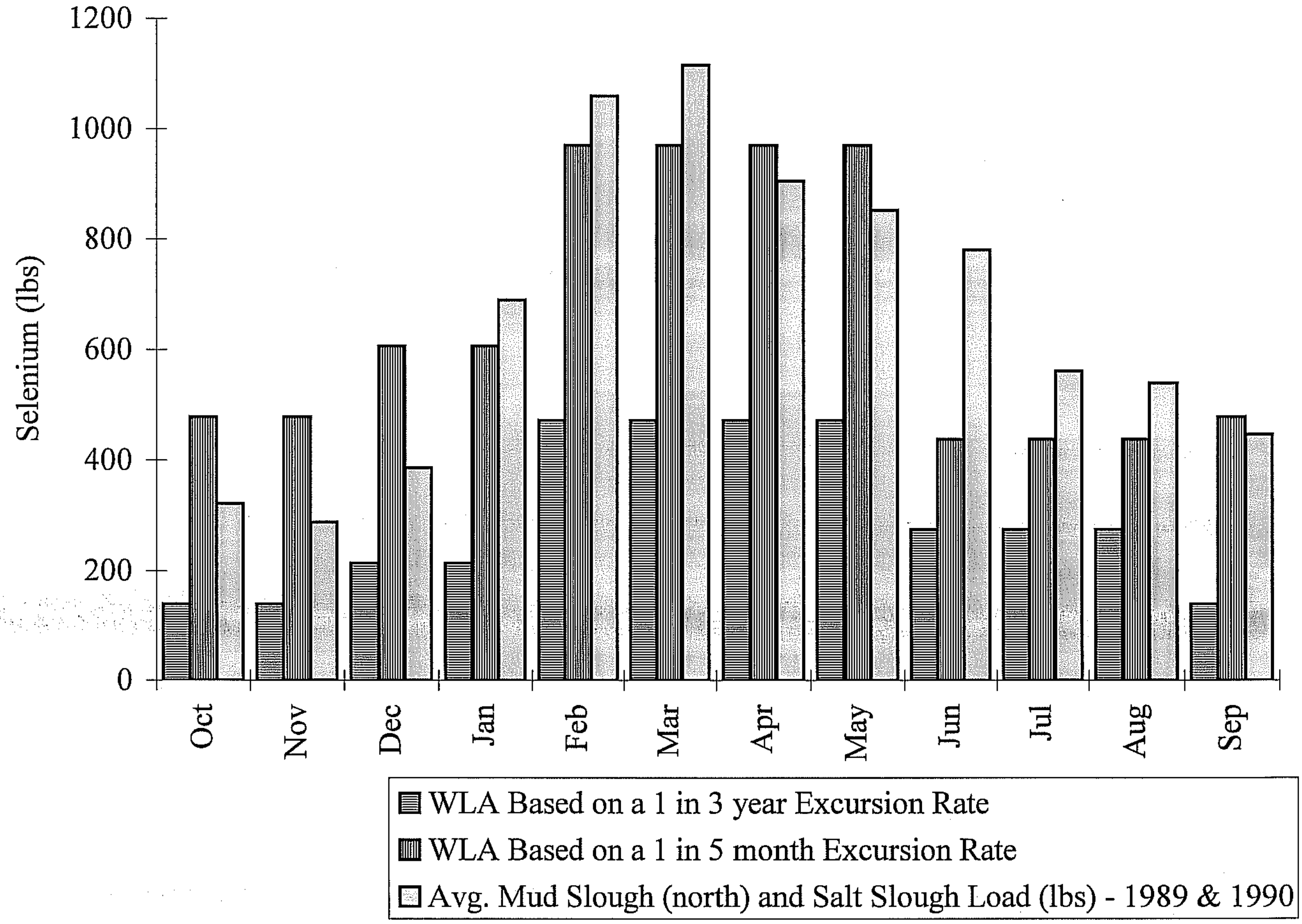


FIGURE 14 (a)

Selenium (Se) vs. Electrical Conductivity (EC) for the Panoche Drain, February - August, CVRWQCB Data WY 1988-92

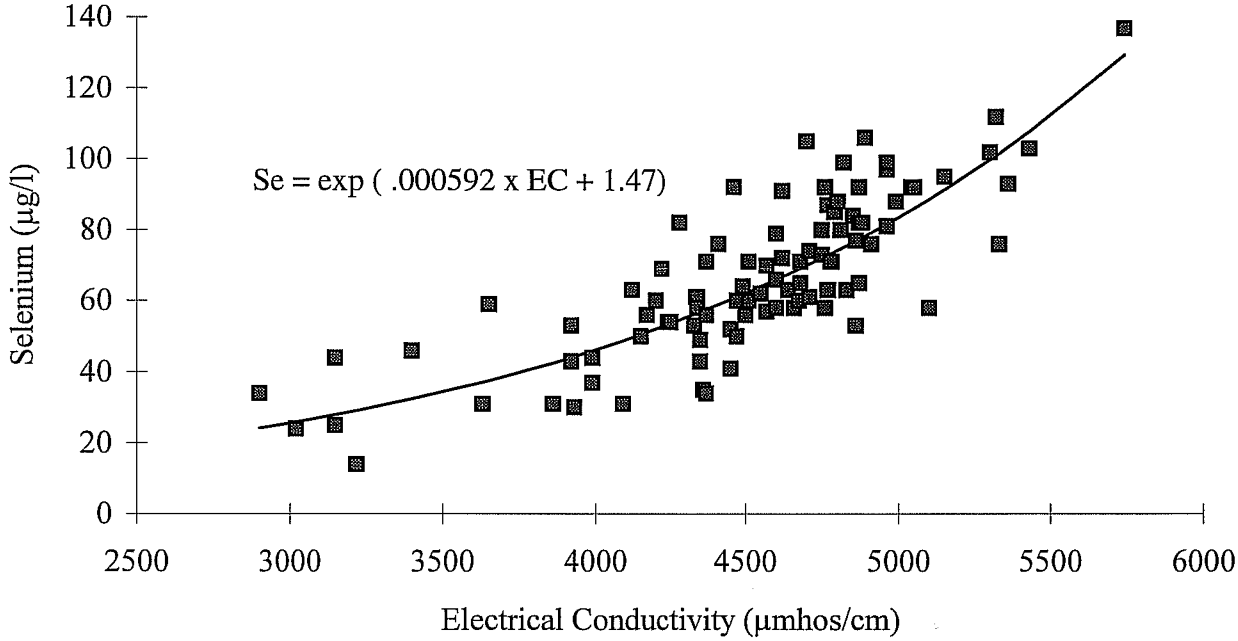


FIGURE 14 (b)

Selenium (Se) vs. Electrical Conductivity (EC) for the Panoche Drain, September - January, CVRWQCB Data WY 1988-92